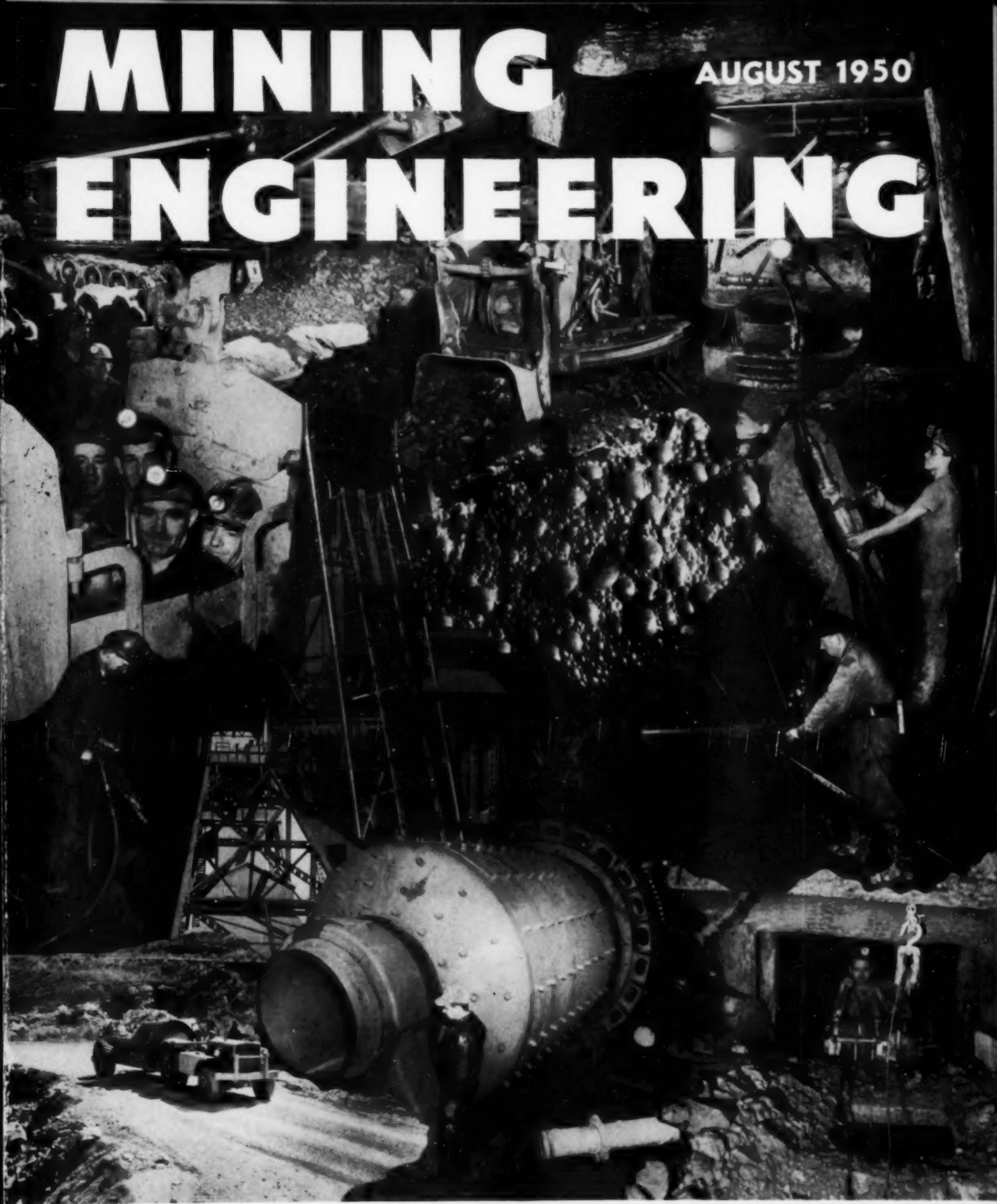
MINING ENGINEERING

AUGUST 1950



Mechanization and Metal Mining Equipment Show Number

Programs of { AMC Metal Mining Convention & Exposition
AIME Minerals Beneficiation Division Meeting

MINING ENGINEERING

Incorporating Mining and Metallurgy, Mining Technology and Coal Technology

VOL. 187 NO. 8 AUGUST 1950

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FEATURES

ARTICLES

TRANSACTIONS

Manufacturers' Bulletins

For your convenience, a listing of booklets and other material currently being offered by the manufacturers. To obtain this information, merely circle the desired number on the coupon, and return it to MINING ENGINEERING.

1) MINING MACHINERY: Bulletin 144 issued by *Wellman Engineering Co.* illustrates the various types of equipment Wellman is prepared to build. For over 50 years they have supplied such machinery as skip hoists, bridges, dumpers, furnaces, etc., for use in the iron and steel industry, shipyards, chemical industry and mining industry.

2) CORROSION CONTROL: A new folder offered by *Calgon, Inc.*, describes a new treatment of protecting water systems against general corrosive attack. The threshold treatment with Calgon will control corrosion in water supply systems to such an extent that it will cease to be an operating problem.

3) DREDGE PUMPS: A new solids handling pump that increases the life of working parts from 400 to 1000 pct is illustrated in bulletin from *Thomas Foundries Inc.* All working parts are made of an extremely hard, abrasion resistant Ni-Cr-Fe alloy. A water jacket is provided between the shell liner and outer casing to prevent breakage.

4) AUTOMATIC CONTROLS: A new line of automatic speed controls for the *Link-Belt* P.I.V. variable speed drive is outlined in booklet 2349. These controls are available in four basic types: electronic, hydraulic, pneumatic, and mechanical. They are job-engineered for automatically controlling the output speed ranges of the P.I.V.

5) MINERAL JIG: Bulletin J2-B8 describes the *Denver Equipment Co.* selective mineral jig. An improved pulsating selector, it treats unclassified, unsized feed. Cross-sectional illustrations showing the operating principle, and flow sheets from various operating plants using the jig are illustrated.

6) RUBBER PRODUCTS: A new 104-page catalog distributed by *Boston Woven Hose & Rubber Co.* describes the entire line of industrial rubber hose. Alphabetically listed, are hoses for insulation blowing, dredge sleeves, air, acid and many others. A section is also devoted to transmission, conveyor, and elevator belts.

7) BLASTING PRACTICE: Circular 7567 issued by the *Bureau of Mines* describes the blasting practices at Miami Copper Co.'s mine at Miami, Ariz. Electrical blasting has been used exclusively and the report contains illustrations of the equipment, diagrams of blasting circuits, storage and transportation procedures.

8) SUBMERSIBLE PUMP: Subette is the name of this motor-pump designed for pumping from deep wells having an inside diam of 6 in. or larger. It is illustrated in bulletin 50-5300 offered by *Byron-Jackson Co.*

9) PIPE PRODUCTS: *Midwest Piping & Supply Co., Inc.*, has published a new 184-page catalog containing data on its entire line of welding fittings. A technical reference section for engineers of welded piping systems is included. ASTM and ASA specifications, charts, tables, graphs, design formulas, metallurgical information and a complete pictorial index of the line of fittings are illustrated.

10) MAGNETIC SEPARATOR: The design features of three models are illustrated in catalog C-1100-A distributed by *Dings Magnetic Separator Co.* The Perma-Drum can be used for reclamation of iron from foundry refuse, tramp iron removal, and scrap separation.

11) COAL PREPARATION EQUIPMENT: Mechanical cleaning units installed in plants, designed, erected and equipped by *Jeffrey Mfg. Co.*, are described in bulletin 815. Coal washing jigs, unit washeries, conveyors, feeders, bucket elevators and other equipment are illustrated.

12) DC MOTORS: These motors are available in drip-proof, totally enclosed gearmotor construction. Design, construction, and ordering information on motors from ¾ to 1000 hp are included in bulletin C-2001 offered by *Reliance Electric & Engineering Co.*

13) CHEMICAL CONSTRUCTION MATERIALS: Bulletin MCC 1 issued by *Atlas Mineral Products Co.* describes corrosion-proof lining, cements, brick sheathings, protective coatings, acid-proof brick and tile, and estimating data.

14) UNIONS AND VALVES: The entire line of hot forged steel unions and valves, sizes, and prices are illustrated in catalog 11 distributed by *Catawissa Valve & Fittings Co.* The unions and valves are shown in cross-sectional views. Dimensions and weights of steel pipe are included.

15) POLYPHASE ELECTRIC MOTORS: A complete line of polyphase motors is offered by *A. O. Smith Corp.* Bulletin EM4-812 describes 1 to 75 hp horizontal motors, illustrating the construction details in cross-

(*Continued on page* 827)

Mining Engineering
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New York 18, N. Y.

August

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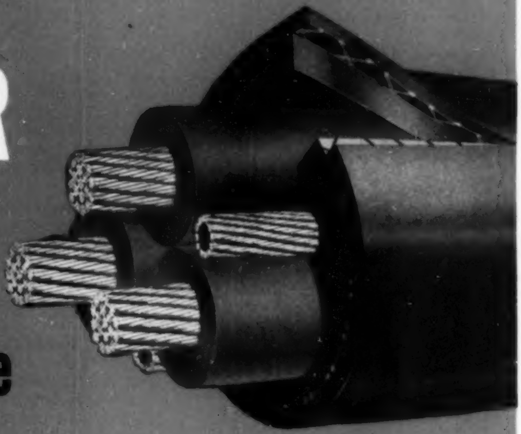
Anaconda introduces COLD RUBBER in SECURITYFLEX 600-Volt Mine Cable



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sectional and cutaway views. Insulation, bearings, ventilation, mounting, etc., are some of the features discussed.

16) SEAMLESS TUBING: Booklet 117, available from *Tube Reducing Corp.*, gives tolerance, finish and application data on compression-formed tubing. It contains tables with profilometer readings for close tolerance tubes and a drawing covering depth of decarburization.

17) MINE AIR COMPRESSOR: A new technical data bulletin sheet, E-235, summarizes and illustrates the outstanding mechanical features of the *Davey Compressor Co.* models. All compressors are equipped with metal housings that totally enclose all working parts and are especially well adapted for roof-bolting.

18) ROPE CHART: A wall chart has been designed by *New Bedford Cordage Co.* which gives specifications on nylon, sisal, and manila rope. Rope diameter, circumference, breaking strength, and working strength are some of the data included. Other various ropes are also listed.

19) BATTERY CHARGES: Bulletin 12-210 illustrates the various models of mine-type battery chargers distributed by *Electric Products Co.* A completely automatic operation eliminates the need for specially trained personnel in continuous attendance at charging stations. Ac and dc models are available.

20) FLEXIBLE RUBBER PIPE: An 8-page bulletin explaining economies in costs of installation and maintenance, recommended applications, and case histories, is offered by *Hewitt Rubber Div., Hewitt-Robins Inc.* The comparative qualities of rubber pipe as against metal pipe in many services, exclusive of long lines, are discussed.


AT THE MINE
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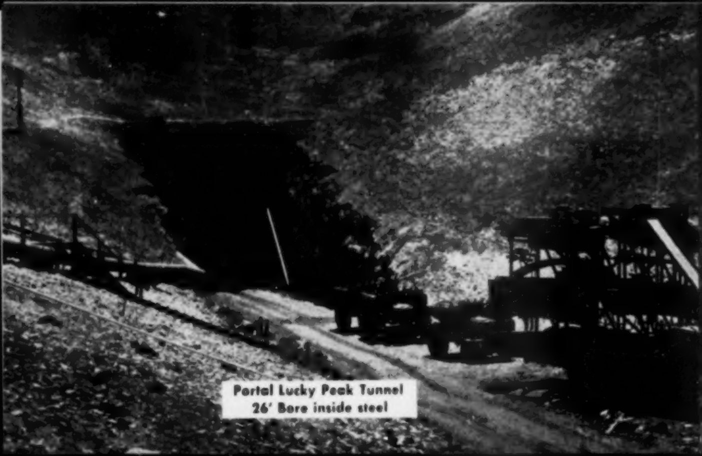

Eimco 104 RockerShovel at Lucky Peak

Lucky Peak Tunnel Project near Boise, Idaho, uses an Eimco 104 RockerShovel for mucking out the 26' bore.

"The 104 is faster and more efficient," says project superintendent Paul C. Guinn, a veteran tunnel driver running the job for the Macco Corporation and Puget Sound Bridge & Dredging Company joint contractors. Lucky Peak is Mr. Guinn's 59th tunnel.

The 104 loads the 8' rounds of blocky basalt rock in three hours using a 1¼ yard rock bucket . . . an average of twenty WD-60 Dumptor loads per hour.

Eimco 104 RockerShovels will cut the cost of loading on your job, too. Write for more information.

"In comparing loaders, the Eimco is a mucking machine," says P. C. Guinn, project manager.

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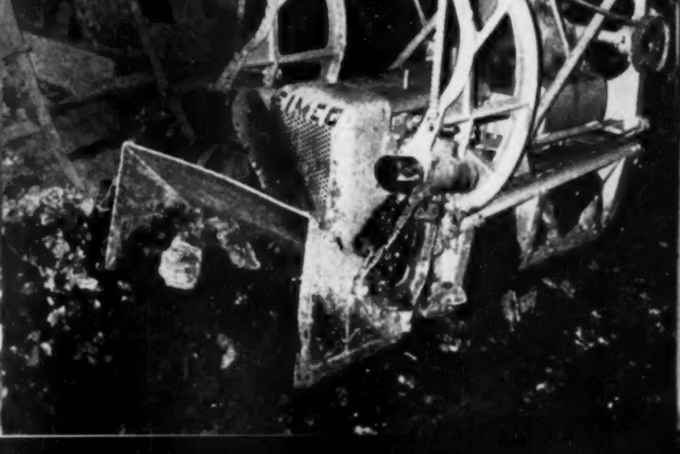
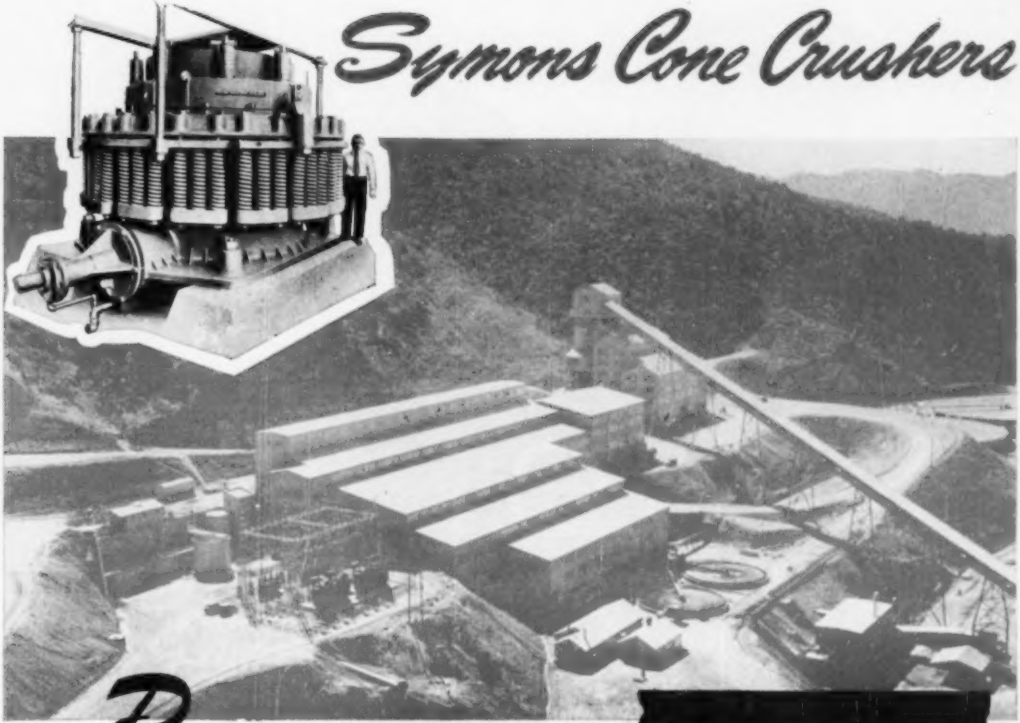


Symons Cone Crushers



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THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18**; 100 Farnsworth Ave., **Detroit**; 57 Post St., **San Francisco**; 84 E. Randolph St., **Chicago 1**. Applicants should address all mail to the proper key numbers in care of the New York office and include 6¢ in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter or $12 a year.

MEN AVAILABLE

Operations Manager, graduate mining engineer, 46; thirteen years' metal mining (open-pit) and concentrating supervision and management. Nine years' general engineering and metal mining. References. Available after July 1. M-558.

Geologist, 27, married, fluent Spanish, graduate Lehigh University, year's graduate work Johns Hopkins University. Some mining experience. Two years' petroleum explorations Colombia, mapping, drafting, developing geological data, assisted supervision 20 laborers. Seek foreign, domestic position as field or subsurface geologist, petrographer, mineralogist, mining geologist, geological draftsman. Six month single status. M-559.

Mining Engineer and Manager, 48, married. Chief Engineer 20 years one West Va. company, preceded by 10 yrs one company Penn. anthracite field. Experienced in deep and strip mining, construction, preparation, buying. Additional details on request. Available for conference. Excellent references. Registered professional engineer West Virginia. M-561.

Mining Engineer-Geologist, 43, married, one child, M.S. Geol. Eng., Europ. ming. engr. degree, 14 years' various superv. positions, consulting valuations, Asia, South America; developing and equipping mines from prospecting to operating stage; tin-tungsten, gold, coals, non-metallics. Speak, write fluently English, Spanish, Russian, German, some French. Now employed, one to two months notice. Desires position assistant exec., liaison mines—headquarters, or exploration-development in field. M-563.

Mining & Metallurgical Engineer, B.A.Sc., M.Sc., desires position suitable to experience which includes all phases of mining, ventilation, assaying, concentration, smelting and research. Especially interested cobalt metallurgy. Location immaterial. Available immediately. Position must offer opportunity to demonstrate engineering and executive ability and capacity for work which will lead to advancement. M-564.

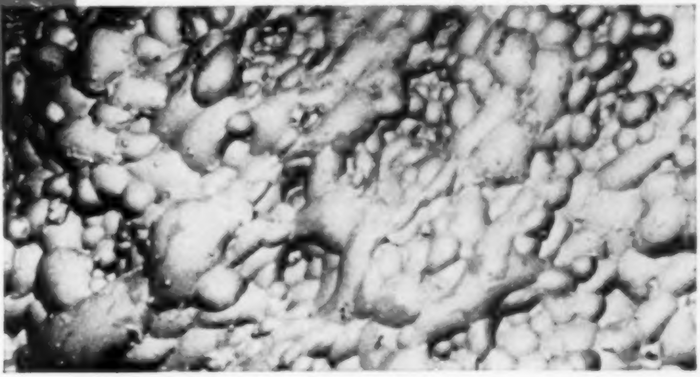
Mining Engineer, 25, single. Indian knowledge of deep level mining and development methods. Four years' experience electrical and magnetic methods of geophysical exploration. Desires position requiring initiative and hard field work, mining and/or geophysical prospecting. Location preferred, U.S.A., Canada or South America. Presently residing in India. M-550.

Dredge or Mill Superintendent, 30, married, no children. Considerable experience, gold, platinum and tin dredging. Milling experience in flotation, gravity and sink-float plants. Available August first. M-566-501-E-7-San Francisco.

(*Continued on page 836*)

Dependable Bear Brand Xanthates

"Over Twenty-Five Years' Experience in Producing Xanthates for Metallurgical Use."



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*From Sharples Amyl Alcohols

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Personnel

(*Continued from p. 833*)

Mine Superintendent - General Foreman, 42, married, one child. Twenty years' experience all types of underground mining, good reputation for production and costs. M.Sc. geology. Five years' experience examination. Fluent Spanish and French. Excellent record for handling Latin-American labor. Location immaterial. Available immediately. M-567.

Mill Superintendent, 57, single. Thirty years' experience in ore testing, mill design and construction and the operation and maintenance of flotation and amalgamation plants. Single, prefer western U. S. Available thirty days notice. M-568-506-E-8-San Francisco.

POSITIONS OPEN

Engineers for large mining company in Bolivia. (a) Chief Geologist with experience in mining geology. $5400 a year. (b) Chief Electrician. $4800 a year. Y3846.

Draftsmen, young, with some mining and metallurgical plant design experience, to be trained for more important work. Permanent position in Southwest, some traveling in Mexico. Y3829.

Division Mine Foreman with underground mining experience, preferably in narrow vein. $350 a month plus room and board for single man. Furnished apartment at end of three months if married, plus $65 a month board allowance. Must speak Spanish. Location, Central America, 5000 foot elevation, moderate climate with dry and rainy seasons. Y3826.

Engineers. (a) Mechanical or Mining Engineers for office engineering work with some previous experience with belt conveyors, bins, hoppers and bulk material handling. $3600-$4800 a year. (b) One mechanical and one electrical engineer with some experience in mechanical and electrical layout, machine shop design and some design as connected with strip mining. $5400-$6000 a year. Location New York, N. Y. Y3783.

Engineers, mature and of good standing, preferably Spanish speaking. (a) Geologist to investigate and report on the possibilities of a mineral bearing area. (b) Mining engineer for work as above. $1200 a month plus expenses. Duration, about three months. Location, South America. Y3765.

Mining Engineers for work consisting of reviewing reports and statistics and drafting final reports based on data supplied. Should be able to write well. Duration about nine months. Location, Washington, D. C. Y3764.


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Authors in This Issue

P. E. LaMoreaux (p. 886) has been with the Ground-Water Branch of the USGS for seven years, and for five of those years has headed ground water investigations in Alabama for the survey. He was born in Chardon, Ohio, went to high school in Geneva, Ohio, and attended Miami University, Denison University, and the University of Alabama, for his B.S. and M.S. degrees. Mr. LaMoreaux lives in Tuscaloosa, enjoys numismatics, philately and golf in his leisure time.

F. C. Bond (p. 871) is well known for his numerous contributions to AIME literature on crushing, grinding, and mineral dressing. Serving now as director of basic industries research for Allis-Chalmers, he has been with that company since 1930. Between that date and 1922, when he took his E.M. from the Colorado School of Mines, Mr. Bond was an assayer in Honduras, an instructor at the Colorado School of Mines, and a designer for Tennessee Copper. He also acquired his M. Sc. at Colorado in 1926. Mr. Bond has authored a book, "Problems Course in Chemistry." He is an AIME member, and also belongs to ACS AAAS, CIM, and the Milwaukee Astronomical Society, among other groups. The erudite Mr. Bond turns to radio experimentation, astronomical theories, and reading in his spare time.

J. T. Wang (p. 871) recently returned to his former position as a professor of mechanical engineering at the University of Chekiang, Hangchow, China, after a tour of duty in the U.S.A. While here, he taught mechanical engineering at Northwestern and was engaged in consulting work for the Allis-Chalmers Basic Industries Department.

R. Q. Shotts (p. 889) holds B.S. and M.S. degrees from the University of Alabama, and has also attended the University of North Carolina. Since 1931 he has taught science and mathematics in high school, worked as a TVA geologist, as a metallurgist with Le Tourneau Co. of Ga., and has taught chemistry, geology and engineering at The Citadel and the University of Alabama, where he is now associate professor of fuel engineering. Prof. Shotts is an AIME member, and this is his second TP. He lives in Tuscaloosa, where the weekends find him teaching Men's Sunday School class, and enjoying the reading of history and philosophy.

H. Rush Spedden (p. 879) has presented three other TP's on mineral dressing before the Institute. An assistant professor of mineral dressing at MIT, he first went to that school in 1940, as a research assistant and instructor. Later he was sent to Bolivia as a production specialist for the U.S. Foreign Economic Administration, and the war years found him a lieutenant in the Corps of Engineers. Born in Colville, Wash., he attended high school in Spokane, and went to the University of Washington and the Montana School of Mines, acquiring an M.A. degree. Prof. Spedden lives in Worcester, Mass., where he turns to photography, canoeing, skiing, and camping for relaxation.

A. Thunaes (p. 879) was born in Norway, attended high school in Oslo, and took his degree in metallurgy from Norway's Institute of Technology in 1923. He has been research and tin plant engineer for the Consolidated Mining & Smelting Co., Kimberley, B.C., Canada, chief metallurgist for Patino Mines & Enterprises in Bolivia, and is now chief of the radioactivity division, mines branch, department of mines and technical surveys, Ottawa. True to his Norwegian heritage, Mr. Thunaes enjoys skiing in his leisure hours.

B. Gildersleeve (p. 883) is chief of the regional minerals section in the division of chemical engineering of the Tennessee Valley Authority at Knoxville. Born in Damascus, Va., he attended high school there and went on to the University of Virginia and Johns Hopkins University, taking B.S., M.S., and Ph.D. degrees. He has been with TVA since 1934.

I. B. Joralemon (p. 852) needs little introduction to AIME members, having done considerable work for the Institute since he joined in 1912. He is a Past Director, and has served on numerous committees. He is also well known for his book, "Romantic Copper." Mr. Joralemon has been a consultant since 1923. He began his career with the Calumet and Arizona Mining Co., becoming chief geologist there, did examinations for Anaconda, and further geological work in Siberia. He was in the Army Air Service during World War I.

* A new curriculum for combined liberal arts-engineering education has been announced by 6 middle western colleges. The plan involves three years of study at one of the 5 liberal arts colleges and two years and a summer of engineering work at Case; graduates receive both the A.B. and B.S. degrees.

* A new kind of mining is being pioneered by a West Virginia coal operator which enables four men to produce 800 tons of coal a day. The machine that makes this possible is a giant auger, 5 ft in diam and 100 ft long. Together with the carriage in which it is moved about, it weighs 60 tons. A mobile, but separate power plant of 1000 hp drives it.

* The Sorel smelter, which will reduce Allard Lake titanium ores, will utilize five 6-electrode rectangular electric furnaces. Furnace hearth size will be about 18x50 ft, and the furnace will smelt about 300 tons of ore per day, producing 100 tons of iron and 130 tons of 70 pct TiO_2 slag. The furnaces will be fed continuously by gravity from charge bins, and tap at intervals of 4 hr or more. Slag will be transferred to a high speed casting machine, using cast iron molds, then crushed for shipment to pigment producers. The iron will be treated to reduce its sulphur content to 0.03 to 0.05 pct, and then cast into small pigs or ingots for shipment to steel mills.

* Flying of North Africa's first airborne mangetometer survey was completed this month, covering approximately 20,000 sq km in north central Tunisia for Gulf Exploration Co.'s program there. Mapping was completed in less than 30 days.

* More than 9000 employees of 11 electric companies are enrolled in a 6-hr program that successfully informs workers on the principles of the American economic system. The course is given by the Middle West Service Co. which claims that before and after employee opinion polls show that the course instilled a better understanding of free enterprise and consequently a favorable response to it.

* According to a report issued by the American Geological Institute there will be 2865 graduates in geology, including advanced degrees from U.S. colleges in 1950. This supply of geologists compares with requirements for 1278 at the professional and subprofessional levels. The report contains a detailed statistical study of the supply and demand situation for geologists in the 1949-50 period.

* The dark cloud of over-production in the bituminous coal industry has a silver lining, according to Natural Resources Notes. Closing marginal mines, mostly strip and truck mines, will result in lower average costs and higher quality of the coal still produced. The producers that will then constitute the industry will be properly equipped and adequately financed to carry forward an intensive campaign to hold and increase the markets for bituminous coal.

* A light, compact, highly reliable blasting machine which does not rely for its effectiveness on the operator's skill is being tested by the Army Engineers. Operating under all climatic conditions from -65 to 125F, the 50-cap machine consists of a springwound dc generator and is waterproof.

Mechanization—Fundamentals and Future Needs

Guest Editorial by James Boyd, Director, U. S. Bureau of Mines

MECHANIZATION of mining, which has made great strides in the United States during the past 25 years, has enabled the production of tremendous ore tonnages despite the fact that the complexities of underground mining have increased. The trend toward mechanization has been stimulated not only by the progressiveness of management but also by the steadily mounting costs of labor and materials.

It has been axiomatic that equipment designed for this purpose be constructed to resist shock, corrosion, and the abrasive action of rock dusts. Underground machinery should be safe and foolproof, capable of withstanding abuse caused by carelessness, lack of training, or failure on the part of the operator. Further, the machinery should be mobile and adapted to easy lubrication and quick repairs, preferably on the job. Finally, such equipment must be economical in use. All of these factors distinguish between the practical and the impractical mine machine, successful or unsuccessful underground mechanization.

There is another factor fundamental to underground mechanization—that of power. Fifty years ago, with the exception of explosives, steam hoisting machinery, and steam driven compressors, our underground metal mines operated largely by manpower or mule power. The development of efficient means for transmitting electrical energy has permitted the direct application of power where it is needed but we are obliged to string electric cables, cut transformer stations, and we still must install expensive compressed air pipelines.

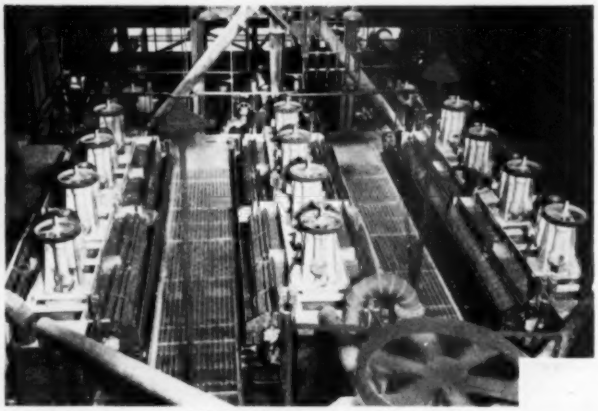
Mechanization has made its greatest advances, of course, in the larger operations. The smaller units have lagged behind not because management was less progressive, less venturesome, or favored with lower labor costs, but primarily because unit costs of operation and maintenance of modern mine machinery were relatively high. For example, many operations produced insufficient tonnages or had too few working places to run their equipment at full capacity; many small mines could not afford adequate shop facilities; and small operations had difficulty in training or hiring skilled machine operators.

Our prospectors and small mine operators need and can use more mechanical equipment. A great service to the minerals industry would be performed if reliable equipment could be designed and produced especially for small operations at a price and with operating costs which they could afford. There is a wide open field for the manufacture of machinery that is largely self-contained and capable of generating its own power. Perhaps further development of diesel-operated units, free from health hazards, is a solution to some of the difficulties.

Mechanization of mining is a field in which many members of AIME have pioneered. Opportunities for even greater achievements in this direction remain open.

James Boyd

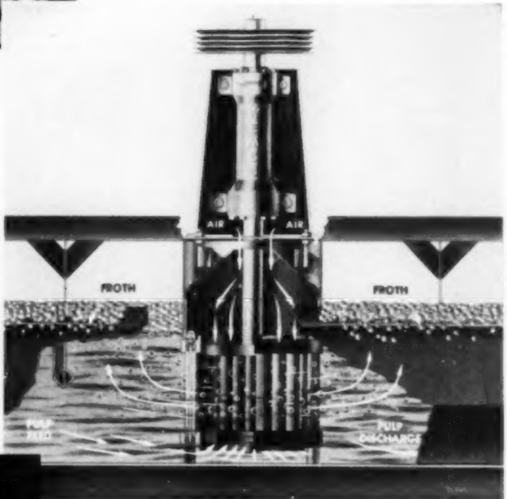
ANOTHER CASE OF RESULTS WITH FAGERGREN FLOTATION MACHINES!



Typical Fagergren installation at American Cyanamid Co. Sydney mine at Brewster, Florida, floating phosphates.

- Zinc concentrate grade up from 57% to 60%.
- Rougher tailings reduced from 2.5% to 0.6% zinc.
- Horsepower and reagent consumption lowered.

Typical of many installations where Fagergrens are used as both roughers and cleaners, these outstanding results were recently reported by a prominent zinc producer. A conversion from another make machine to Fagergrens provided convincing proof of Fagergren superiority in roughing and cleaning.



HIGH METALLURGICAL EFFICIENCY is a direct result of the thorough dispersion of air achieved by the Fagergren rotor-stator design, which together with simple, rugged construction brings these important advantages to operators throughout the world:

- High mineral recovery.
- Minimum reagent consumption.
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It's Everyone's Business

THE research and policy committee of the Committee for Economic Development, a non-profit research organization composed of leaders in industry and the professions, including such prominent figures as Dwight D. Eisenhower, Paul G. Hoffman, and Charles E. Wilson, recently published a report entitled "How to Raise Real Wages." Since its founding in 1942 the CED has initiated many objective studies on matters of national economic policy, and has gained a fair measure of prestige from its activities.

The CED's latest report cites the more than threefold rise in real wages in the United States in the past 50 years and attributes the accompanying improvement in the standard of living to the great increase in production per man hour. The report states that in order for production to continue rising in the future with the attendant increase in real wages four basic conditions must be manifest: (1) better methods, (2) more capital, (3) better training of workers, and (4) better management. The report cautions that although prospects for increases in output per man hour are good "it is desirable that steps be taken to encourage such a rise."

Among the recommendations made to this end was one that stated "reform the tax system to make risk-taking more attractive." By way of explaining this recommendation the report presents the following comment: "Insofar as possible, the tax system should avoid imposing special burdens upon hazardous ventures. A tax system which artificially causes would-be investors to prefer safe investments discourages pioneering, makes the economy less progressive, and therefore retards the rise in the standard of living."

Although the report does not mention any specific industry this recommendation appears particularly appropriate for the domestic mining industry. Many share the opinion that payments for exploration and development should be authorized by Congress. Others prefer subsidies of a more general nature. An imposing group both in the industry and in Government advocate a tax incentive program to stimulate investment in mining enterprises. This group would be quick to capitalize on the recommendation of the CED.

Along this vein the six-point tax incentive program of the National Minerals Advisory Council should be mentioned. These recommendations, placed before the Secretary of the Interior last December, are as follows:

1 Allowance for depletion should be made to the stockholder as well as to the corporation.

2 Tax exemption should be granted to a mine for a period of at least three years after beginning of profitable operations.

3 Development costs after discovery should be recognized as operating expenses.

4 Adequate allowances for percentage depletion should be made.

5 Losses from unprofitable ventures should be allowed corporations, partnerships or individuals as ordinary deduction against current income.

6 Income should not be taxed without full allowance for losses of loss years.

Some mining authorities believe that the industry should seek relief only in those areas in which mining differs substantially from other industries, namely, in the field of exploration and development and in depletion allowances.

Regardless of differences of opinion within the mining industry as to what course should be pursued to encourage not only steadily rising production but a substantial increase in exploration for, and development of new ore bodies, a common ground should be sought on which the mining industry as a whole can unite. It appears that the most acceptable basis for collective action is a tax incentive program. It behooves the mining industry to resolve its many diverse interests in a program touching upon a vital aspect most common to all. To many, the CED's recommendation when applied to mining hits the nail squarely on the head.

Copper is a subject of much controversy at this time. There is duty of 2¢ per lb on imported copper for the first time since before the war. For the past few months copper supply has been tight in the face of a near-record postwar demand. This situation has enhanced the price to its present level.

As the June 30th deadline for the suspension of the import duty approached some observers felt that the recovery in the price precluded any action to restore the import duty. Nevertheless, the Senate failed to pass a House-approved resolution (H. J. Res. 494) to extend the suspension another 60 days, and the duty went into effect. To date, the Senate Finance Committee has not taken any action on this resolution, which was designed to forestall reimposition of the duty until a more permanent measure could be enacted.

Proponents of the Administration bill (H. R. 7151) to extend the duty-free period for two years emphasize that domestic production of copper is inadequate to fill our needs and that to discontinue the suspension of the import duty will reduce the continuous supply of copper. Opponents of the measure contend that the import tax is needed to compensate for higher U. S. mine costs so that domestic producers can meet the sting of competition from abroad.

It seems that prospects for a two-year extension of the duty suspension have improved with developments in Korea. At least, the Korean war will probably hasten action on the measure.

American intervention in the Korean war gives rise to speculation as to the duration of the hostilities and the extent to which this country will participate. For the mining industry this development quite possibly may mean changes in the Munitions Board's stockpiling program and will likely have an effect on metal prices. At present the stockpiling program is influential as a market force itself. This can be seen in the light of the recent drop in the price of lead from 12 to 11¢ per lb just about the time the Munitions Board officials told an industry advisory committee on nonferrous metals (June 13) that purchase of lead for the stockpile will be reduced after July 1. The price of lead had partially recovered from 10.5¢ per lb in March to 12¢ by the middle of May.

The Munitions Board announced to its advisory committee that stockpiling of copper and zinc will continue at the present rate, thus bolstering already rapidly recovering copper and zinc markets. Zinc rose from a low of 9.75¢ per lb in mid-March to 15¢ by mid-June and will probably continue its upward trend.

Zinc producers suggested at the recent meeting with the Munitions Board that the Government spread its purchases of the metal so as to reduce the effect of federal buying on the market. However, Board officials rejoined that defense needs must have first consideration. It is conceded by many that with the present short supply of zinc large Government purchases of that metal would have a telling effect on supply and price.

Mechanization and Incentives Cut Cost at

by John G. Hall

The unstable metal market during 1949, with resulting lower metal prices, has focused every mine operator's attention on the problem of reducing operating costs. Improvement in mining methods, use of modern mechanical mining equipment, and increasing the efficiency of the labor force are the tools with which we will have to work. Careful planning is necessary to coordinate all phases so that no one phase is overdone. A mine may become over-mechanized if, for instance, capital charges against new equipment exceed the savings in labor costs, or where a large enough tonnage is not produced. The cooperation of labor is essential to any mechanization program. There have been too many instances where mechanization and improvements have done nothing more than make up for a decrease in labor efficiency, thus bringing the production of labor back to its old standard. The operator has gained little and labor has gained only a "softer job." In any mechanization program there are gains to be had by both the operator and labor. By the efficient application of modern equipment and improved mining methods the operator should gain by decreased costs, and labor may profit by receiving a share of these decreased costs.

Mr. Hall is general superintendent of the Chief Consolidated Mining Co., Eureka, Utah, and an AIME member.

Since labor is a large proportion of the cost per ton at any mine, it will be well to consider this problem first, and present a brief outline of the manner in which the Chief Consolidated Mining Co. has tackled this problem. Approximately 90 pct of the underground labor and supervisory force are working on an incentive plan, in which savings due to increased efficiency are shared by the company and the men. All stoping operations are on an incentive plan based on tons produced per manshift in each individual stope. The system is flexible so that the basic tonnage may be varied to suit conditions in each stope. Under this system each stope crew can easily calculate the bonus earned each day, since mine cars average one ton each.

An average base of 9 tons per manshift is required for stope crews before bonus payments begin. All development and exploration operations are on an incentive plan based on footage advance. The average drift contract is based on payments of $6 per ft advance. All hoisting, caging, and haulage operations are on incentives based on tonnage handled. Diamond drilling, timbering, track work, and shaft work are also handled on special incentive systems.

The supervisory staff also participates in the incentive system on a plan that takes into consideration grade of ore and profit. Hence, they are given a definite incentive to maintain quality while the miners' incentive is to produce as much tonnage or footage as possible. This entire incentive system has been planned so that there is greater output per manshift, larger bonuses are earned, and the cost to the company is lowered.

The introduction of mechanical equipment, and improved mining methods with the wholehearted cooperation of the employees has made possible the successful functioning of the incentive system.

A most important improvement has been in the stoping methods. The old expensive square methods have been replaced by cheaper openstoping (with temporary pillars), modified shrinkage, and various stringer set and stulling meth-

Miner Duane Milne using a Sullivan hydro jib jumbo to collar a cross cut off the main drift on the 1100 level at the Chief mine.

Chief Consolidated Mine

ods. These changes have in part been made possible by the application of mucking machines and slushers.

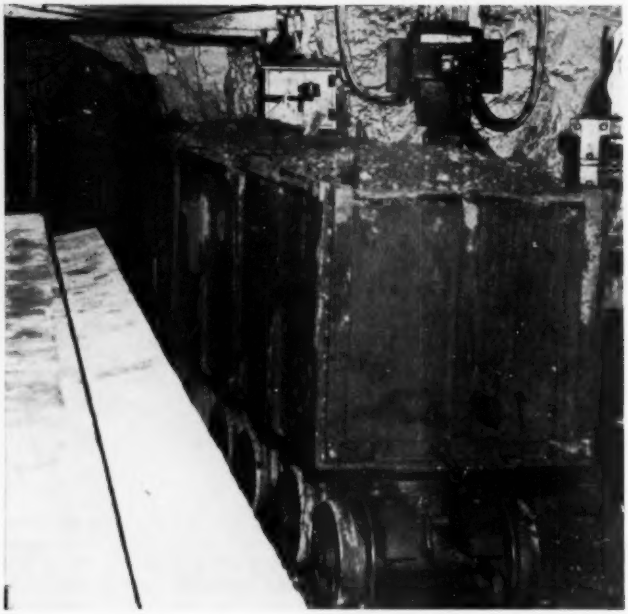
A test is now being conducted on the use of roof bolts for back support. This is of course a proven method that has been long used by the St. Joseph Lead Co. in southeastern Missouri and is used somewhat in coal mining but has been little used in western metal mines. Possibly the reason for the delay in acceptance by the practical miner is that the method appears at first glance to approximate "holding one's self up by one's bootstraps." In fact many persons have suggested the name "sky-hooks" for the bolts, but the method is scientifically sound. It involves a method of applying re-enforcing material to provide additional beam strength. Roof rocks have planes of weakness owing to thin bedding, faulting or fracturing, which during mining may be bound together with bolts to form competent beams across openings. It is particularly adaptable to relatively flat bedded deposits with incompetent hanging walls. Practice is to drill 5-ft. holes into the back with a stoper using 1½-in. insert bits. The holes are placed on 3 to 4-ft. centers. A 1-in. x 5-ft bolt, with an expansion wedge on the upper end, is seated into the hole with the stoper, then an 8x8x¾-in. plate is placed on the bolt and the nut is tightened against the plate with an air operated impact wrench. Two other types of bolts, made by Cleveland Foundry, and Ohio Brass Co. are also about to be tested. The bolts are installed by the miners as stoping proceeds. The most important thing is to get the roof bolts in place before the back has had any chance to move or loosen. Test work has not proceeded far enough to be able to give final results, but from all indications is going to be very successful. There are, of course, many different roof bolting practices which vary from the method described and each suited to particular situations.

A Utah Section contribution

The use of 1½ and 1⅝-in. tungsten-carbide insert detachable bits has led to reduced drilling costs. The bits have averaged in excess of 150 times the footage of ordinary detachable bits, and drilling speed has been increased considerably. In hard ore their use has permitted a stope round to be drilled out in one shift instead of two, and has made the use of 7 ft and 9 ft "bonus" steel a common thing, thereby increasing tons broken per drill-shift. The use of the insert bit has been limited to hard ground. The miners can obtain bits only with permission of the shift bosses and then must sign for them at the warehouse, and return them when dull. Bits are resharpened an average of three times and are gaged in increments of 1/32 in. Bits are then dipped in paint to identify each bit size. Bits are discarded when gage is —1⅜ in. Tests on single use or throwaway bits have been encouraging, but the fact that no throwaway bit attachment has been developed to interchange with a carbide tipped bit has discouraged adoption of a throwaway bit.

Improvements in ventilation at all working faces have led to hidden yet important improvement in over-all efficiency of the miners. The barely adequate natural ventilation heretofore relied upon has been supplemented by a 30,000 cu ft fan, and directed air-flow, controlled by air doors. Adequate ventilation is thus supplied to all main drifts. The most important ventilation improvement has been the installation of many small auxiliary fans ranging from 1 to 15 hp. to supply fresh air to working faces. The use of 10-ft sections of heavy corrugated vent pipe near the working face has allowed vent pipe to be kept close to the working face, minimizing damage due to blasting.

Results obtained from a mechanized stope working on the incentive stoping system for a 3-month period when the nature of the ore body allows large rounds to be drilled show: 30 tons per manshift, 83¢ per ton for labor, and earnings of $25 per man per shift. Had this stope crew produced only the basic tonnage the labor cost per ton would have been $1.55 per ton and the

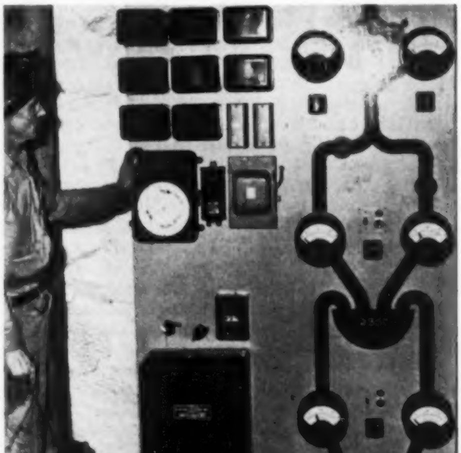


Tramming costs have been lowered and production increased by the use of $1\frac{1}{2}$-ton battery locomotives and solid box cars. Here a Mancha motor hauls cars full of ore along the 1800 level to the main shaft where they will be hoisted to the surface.

men would have earned $10.85 per man per shift. One vitally important point which should be the basis for any successful incentive plan is that earnings alone should not determine the basic contract rate. In other words, if a crew earns $25 per man per shift on a contract that has been established as a fair rate for the company and the men, then it should not be cut simply because the men are earning $25 per shift. Contract rates should only be cut if stoping conditions have changed so that the calculated base rate has increased due to increased width of ore body or if improved facilities have been provided for the operation.

Drifting costs have been reduced in operations already using mechanical mucking machines by the introduction of the hydraulic jib jumbos with 8-ft feed, insert bits together with the use of a $3\frac{1}{4}$-in. pilot-reamer bit for the cut hole, $1\frac{1}{2}$-ton battery locomotives, and the cooperation of the drift crews. Before the introduction of the above mentioned equipment the standard contract rate for drifting was $9.75 per ft for labor. Today a drift equipped as above has a contract rate of $6 per ft for labor, and crews are making better footage. Drift crews have been reduced from three to two-men crews. Drift crews are now averaging approximately 6.5 ft per shift, where only a single heading is provided, and up to 14.5 ft per shift where two or more headings are provided and conditions have been made ideal.

In tramming operations the introduction of $1\frac{1}{2}$-ton battery locomotives throughout the mine has reduced tramming costs and increased production. Where the contract base rate for a hand trammer was 27 cars per shift, it is now 52 cars per shift for a motorman. The use of gravity operated rotary dumpers at surface dumping points, and the use of 8-ton haulage trucks has materially reduced surface tramming costs. The use of rotary dumpers has led to the design of a doorless solid box mine car to replace old end dump cars with doors. By eliminating the dumping mechanism it was possible to increase the capacity of the cars from 18 cu ft to $23\frac{1}{2}$ cu ft without changing over-all dimensions of the car. This 24 pct increase in car volume has reflected itself in increased hoisting capacity as cars are



Alton Baker, chief electrician, views an automatic pump control panel he designed and built. Major pumps are controlled from here.

hoisted on cages and in increased tramming capacity, thus reducing costs of these operations. The use of the solid box car has eliminated spillage from cars along haulage drifts, and reduced car repair and maintenance costs.

Pumping operations have been made completely automatic by use of automatic throttling valves and variable speed pump motors both controlled by floats in the sumps. As a safeguard pumpmen are still maintained, but most of their time is devoted to the caging of cars in the hoisting operation. Pumping involves 4200 gpm at a tdh of 1000 ft or about 60 tons of water to each ton of ore extracted.

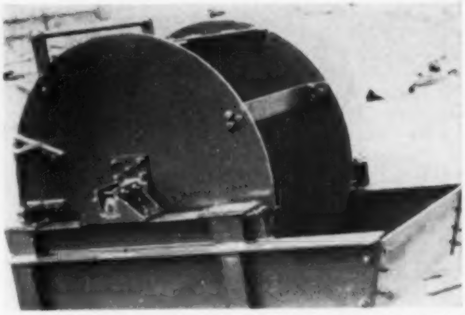
Miscellaneous mechanical improvements include an electronic signal bell that may be operated from a moving cage, which has been successful even though cages are subjected to constant heavy shocks on the shaft chairs. It has also proved useful in shaft inspection and maintenance work.

Stainless steel lag bolts which replace common iron bolts in shaft guides in wet shafts have reduced repair costs and created safer hoisting conditions. Common iron lag bolts rust away in about one year, but after a year there is no visual change in the stainless bolt. Replacing broken and rusted lag screws in the main shaft is now a major job.

The use of a metalizing spray gun to galvanize all types of equipment and to rebuild worn pump parts and all types of shafts has been a big costcutter in our shops. A battery locomotive and battery box have recently been completely metalized with a zinc coating for use in extreme wet conditions where rusting has heretofore led to excessive repairs on the locomotives.

The use of pressure treated creosoted timber and timber dipped in other preservatives in main haulage drifts and other permanent timber jobs has increased timber life considerably.

In development and exploration work the use of diamond drilling has become much more important. At present approximately one ft of diamond drilling for each ft of development work is being done. Geochemical analysis, or trace determinations of copper, lead, and zinc in wall rock and fault zones is another prospecting tool being used on an experimental basis. Work has not proceeded far enough to be able to give the results, but it appears there are definite applications of this technique to underground prospecting.



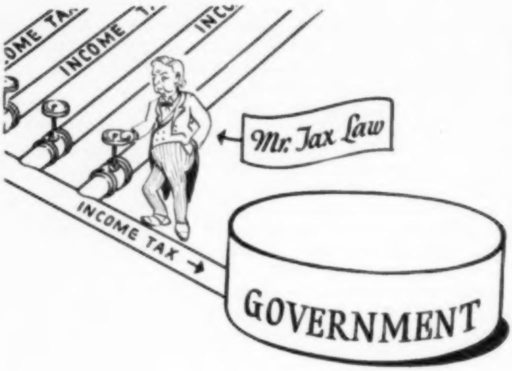
Rotary mine car dumper designed and built by the Chief shops. This led to use of solid box mine cars, increasing car capacity by 5½ tons.

The use of small booster compressors located near active areas to supplement the main air supply and maintain high air pressures has aided greatly. The boosters are automatically controlled to start at 90 lb and cut out at 104 lb and thus operate only as needed. Maintaining the air pressure from 90 to 100 lb has led to increased drilling speed and decreased drilling cost and has aided the air slusher operations.

The efficient use of modern mechanical equipment has aided in overcoming the effects of the drop in metal prices by helping reduce over-all costs by 16 pct in 1949 as compared to 1948. With the aid of this equipment the over-all production is 3.0 tons per manshift.

Mine staff. Left to right back row: C. A. Fitch, Jr., general manager; C. A. Fitch, Sr., president; J. Kemmer, grandson of Mr. Fitch; H. B. Spencer, mgr., Centennial Development Co.; F. Johnson, lime plant foreman; M. Carter, chief clerk;—Left to right front row: W. Sutherland, shift boss; C. Beck, shift boss; J. Hall, general supt.; W. Bridgeman, shift boss; S. Tregaskis, master mechanic.

What Is Wrong With Independent Mining?



By Ira B. Joralemon

INDIVIDUALS and small companies have discovered and brought into production the mining districts of the United States. Hardly an exception comes to mind, save for the disseminated copper properties and the great iron mines. In spite of this fine record that has made possible the industrial greatness of the country, mining by small companies and by individuals has become a vanishing phenomenon. In Nevada, the lair of rugged individualism, there are fewer operating mines and fewer miners than at any time since the 1860's. The situation in other states is nearly as desperate.

In the four years since the end of the war the few notable developments have been made by great companies. Only a handful of these companies are actively engaged in exploration. They can develop only a small fraction of the prospects that technological advance has made promising, and usually they test only the showings that give hope of making great mines. Out of the prospects they select for development, at the best only one in ten proves even moderately successful. Naturally, the number of new mines found by the large companies is pitifully small.

Mr. Joralemon is a consulting mining engineer and geologist, San Francisco, and a member of AIME. This paper was given before the Mineral Economics Division, February 1950.

Until our knowledge of ore occurrence is infinitely better, nothing can replace the development of thousands of prospects by hundreds of exploring groups. In the absence of such intensive exploration, we are falling far behind in the replacement of ore mined by making new discoveries.

Our welfare in peace and war depends on a continuing supply of metals. The present eclipse of mining and of exploration therefore demands the most careful study. What is wrong with mining and what can be done about it?

The greatest culprit is, beyond question, our short sighted tax policy. The recent report by the National Minerals Advisory Council is a brilliant presentation of the problem and of the cure. Mr. Granville Borden's article "Taxation vs Mineral Resources" which appeared in the April **Mining Engineering** emphasizes the conclusions. Development of mines is a risky venture, and unless hundreds of individuals and small companies can keep, after taxes, sufficient profits from occasional successes to pay for dozens of failures, they will be foolish to try to find new mines. A wealthy man often buys a gentleman farm just for the fun of it, but it will be a long time before gentleman mines come in fashion. Mine exploration must be encouraged by a far sighted tax program like that in Canada, or before long we won't have any mines to tax or any metals for peace or war.

Tax reform is necessary, but it alone will not be adequate. There are not enough mine-minded wealthy persons to finance exploration on the great scale that is necessary to replace ore that is mined. Canada has shown that development by a multitude of small companies is the best way to find many new mines. This is obvious from the maximum one in ten ratio of success. It is equally obvious that the great number of companies can be financed only by participation of many small investors who are willing to risk a loss in return

for a chance of making a great profit. The hundreds of millions of dollars that are bet on horse races or put into slot machines or other gambling games prove that a large share of the people demand the excitement of a possible killing, even where the percentage taken by the house makes a successful outcome in the long run a mathematical impossibility. It is fantastic that laws in so many states encourage parimutuel betting on horse races, and in Nevada permit all forms of gambling, while the issue of speculative mining stocks is hedged about by such strict limitations that participation in exploration by small investors is almost impossible. Our blue sky laws, well intentioned as they are, have diverted into improductive betting the venture spirit that has made most of our past economic progress.

Those who want to take a chance, whether with large sums or with a few dollars, can get much more fun out of a mine development that keeps hope alive for months than out of a race that is over in two minutes. And the result may be a mine that will benefit the economy of the whole country as well as enriching those who buy the stock.

The only essential limitations on selling stock for exploration seem to be, first, that the prospectus should tell the truth, and second, that, as in most Canadian provinces, stock issued to promoters must be put in escrow during the development period. If the promoter can profit only in the event of success, there can be no serious abuse. Such a modification of blue sky laws would go far toward encouraging the great number of small companies that are necessary for successful exploration.

A more liberal attitude toward mine locations is a third change that seems necessary. Certainly no further waiving of assessment work is justified. In peace time it is unreasonable to allow prospectors or companies to hold locations without any attempt to prove their value. However, the old requirement of a hundred dollars worth of work a year per claim, with claims grouped so that only work that benefits contiguous claims can count for the group, is no longer reasonable. The necessity for expensive geological or geophysical study to outline promising hidden areas requires some sort of preliminary claim that will tie up a reasonably large area while the reconnaisance is being carried on. After the reconnaissance, the area could be reduced to claims of the present size. The requirement that ore must be found in place on every claim before patents are granted is no longer of benefit either to the nation or to the miners. Most new ore bodies will be found in areas hidden by a barren capping material, and expensive development under this capping can not be undertaken unless title is sure. When a company has proved that there is reasonable geological evidence that ore is likely to continue under locations in which there are no outcrops, it should be granted a title that will give it possession while orderly development is carried on. Such development may require many years.

The southeastern part of the Bisbee district is an example of the benefit from liberal patents. A deep mass of barren conglomerate covered the ore-bearing rocks, and heavy flows of water delayed development. If the old Calumet & Arizona Mining Co. had not held patents to the ground, it is doubtful if the great Campbell ore body would ever have been developed.

Another useful change in mining law would be to provide that expensive development work done in one year can apply as assessment, for the succeeding 4 or 5 years, on a group of claims in the same district, whether or not these are contiguous. This would encourage true development instead of the useless scratching of the surface that is often done to meet requirements for assessment work.

The whole problem of the enforcement and of desirable changes in mining law is so complicated that there is no general agreement between mining authorities as to the best procedure. Some changes are necessary. The question might well be studied by the National Minerals Advisory Council.

The question of assistance to small or marginal mines by government subsidy or of other government aid is another one on which there is disagreement among representatives of mining companies. To anyone who carries belief in free economy and individual initiative to its logical conclusion, any government subsidy is bad. Unfortunately, subsidies have been accepted as a necessary part of our economic system. Wiping out all protective tariffs would be at least a temporary catastrophe, and subsidies to farmers are as firmly seated on the shoulders of the poor taxpayer. If there are to be subsidies, would they not be more useful if applied to commodities that are becoming scarce, like some of the metals, rather than to those that are in tremendous over supply, like potatoes or eggs? The only argument in favor of the potato grower over the lead miner is the fact that potato growers have more votes. A subsidy for metals is particularly reasonable in the case of mines that are approaching exhaustion, where a shut down would mean a permanent loss of metals that the country may need. Unlike a potato patch, an old mine won't become more productive through lying fallow.

A convincing argument is often advanced for development subsidies or government loans for exploration and equipment of new mines. Such aid is likely to be less effective and more expensive than tax relief. On the whole it seems that government subsidies should be granted only where needed metals will be lost without such aid. The same principle should apply to farm subsidies. Government aid should be in proportion to the need for the product, not to the voting power or lung power of the producers.

Finally, it must be recognized that new mines are becoming harder to find. Exploration requires more money, and the proportion of failures to successful ventures is bound to increase. The limited development that can be carried on either by large companies or by government agencies can not possibly replace the great quantities of metal that are being mined. Only participation by a great number of individuals and of small companies can do this. If we are to continue our economic advantage over other parts of the world, those who hunt for new mines must be looked on as useful citizens and not ruthless exploiters. And the rewards must make the venture of hunting for mines worthwhile.

Inspiration's Successful Change

P&H shovel loading Dart trucks at Inspiration. Tractor is under movable bridge which carries shovel's power cable.

by H. C. Weed

THE Inspiration Consolidated Copper Co., located in the Globe-Miami district at Inspiration, Ariz., became a producer of copper in 1915. From 1915 until 1948, 116,278,000 tons of ore were produced from underground workings by the block-caving system of mining.

In April 1948, open-pit ore production from portions of the ore body was started and earlier plans for block-caving in these areas were abandoned. The change was due to economic conditions.

Prior to the war years Inspiration's costs of mining by block-caving methods were comparable to, or even below, the costs of some open-pit operations. By the end of the war these conditions were completely changed. Underground costs had risen steadily for labor and supplies. Difficulty was being experienced in finding competent underground men and underground development was almost hopelessly behind schedule. On the other hand, open-pit costs had been sharply reduced through the development of modern earth-moving machinery and plenty of labor was available for surface work.

Mr. Weed is general superintendent, Inspiration Consolidated Copper Co., Inspiration, Ariz., and an AIME member.

A study of local conditions indicated that two areas presented possibilities of conversion to open-pit methods: (1) a portion of the Live Oak ore body lying immediately west of the Bull Dog Fault, and (2) a portion of the Colorado area lying immediately east of the same fault. Of these areas, the Colorado was in virgin ground, while the Live Oak had been partially mined by 200, 300, 400, and 450 level mining. Fortunately, one churn drill and one bulldozer were immediately available, and by drilling some prospect holes along the fringes it was possible, relatively early in the studies, to convert sections to bench plans and roughly outline probable pit areas.

The entire Inspiration surface plant lies on the north side of Inspiration ridge, while the two pit areas are on the south side of the ridge. This physical feature left three choices: (1) Trucking over the ridge, (2) dropping the ore through ore passes to the existing 600 level; hauling underground, and hoisting at the Inspiration shafts, or (3) belt conveyor over the ridge. The first of these three methods was chosen as most economical.

Since Inspiration's entire surface crushing plant was designed to handle a maximum of 12-in material, it was necessary to provide a primary crusher before the open-pit ore stream joined the underground ore. It was decided to construct the primary crusher on the north side of the ridge with a 5000-ton ore bin to be serviced by a spur line from the existing Live Oak to Inspiration railroad. No new railroad equipment was necessary and very little additional service time was required.

The dump level at the crusher was at elevation 3968 ft; by cutting through the ridge, haulage roads of 7 pct up-grade could be constructed outside of the pit limits from the lower benches to the crusher. Work on the haulage roads, crusher, and ore bins was contracted, while the equipment for company operation was being ordered and delivered. The work on roads, cuts, and excavations was started March 3, 1947.

After considerable study the following equip-

THIRTY-THREE years of underground operation, which produced 116,278,000 tons of ore, were ended as a result of high labor and supply costs. The development of modern earth-moving machinery and the availability of labor for surface work prompted the change.

to Open-Pit Mining

ment was ordered: one 2½-yd diesel shovel; two 4-yd electric shovels; nine 16-yd dual rear-axle trucks, powered by 240 hp diesel engines; 2 churn drills, motor driven; 1 churn drill, gasoline driven; 3 bulldozers; 1 road grader; one 10-ton mobile crane; one 18-yd carryall; 2 portable compressors; 2 wagon drills; 7 service trucks, together with garage and service equipment to properly take care of the above listed equipment.

Pit headquarters were established in the existing supply yard, the new buildings necessary were a garage, change-room, and pit office. Since starting operations three more duplicate haulage trucks and one additional bulldozer have been purchased. Stripping operations by electric shovel and trucks started in January 1948, some previous work having been done by the diesel shovel. On April 1, 1948, production of ore through the crusher commenced.

Inspiration's benches are laid out in 50-ft vertical intervals and are numbered according to elevation above sea level. In the Live Oak area the top bench was the 4000, and the lowest will be the 3550. This pit follows the pitch of the ore to the west and within the pit limits lies a considerable area previously mined out by underground operations. Its maximum dimensions are approximately 3500x1750 ft, the maximum thickness of ore is 250 ft. Both ore and waste are encountered on every bench.

In the Colorado area the high bench was 4000 and the lowest will be 3450. The maximum dimensions of this pit are approximately 2400x1000 ft, with thickness of ore 350 ft. No ore occurs above the 3800 elevation. Above the 3950 elevation all waste will be removed by bulldozer and carryall. To facilitate early production of ore, advantage was taken of the natural topography. Here the surface sloped sharply from west to east, while the ore remained on a nearly horizontal plane. A temporary western slope line was established where no major stripping had to be done above 3850 elevation, thus allowing ore production at a relatively early date. The remaining stripping on the west end will be carried back in two stages as the opportunity allows.

Drilling and Blasting

Primary blasting practice in the two pits varies because of different ground conditions. In the Live Oak area the ground is harder than in the

One of five 24-ton, 15-cu yd Dart trucks used at the Inspiration open-pit dumping a load of ore into a 42-in. gyratory crusher.

Colorado area. It is also somewhat cracked and fitchery due to adjacent underground mining. In both areas 9-in. churn-drill holes are drilled to a depth of 55 ft, or 5 ft below grade. A 29T drill rig is used for this purpose. A short piece of casing is needed at the collar of the holes.

The hole spacing in the Live Oak area is 18 ft along the bank with a toe burden of 40 ft. The holes are loaded with a primer of 60 pct special gelatin, usually a 100-lb charge. Bag powder of 70 pct strength is the main explosive charge. A deck charge is ordinarily used with a 50-lb gelatin primer. The total charge is made up of approximately 82 pct bag powder and 18 pct gelatin. Double lines of primacord are used here to eliminate the possibility of a single line becoming cut by sharp rocks in the cracked-up ground.

In the Colorado area the hole spacing is 30 ft along the bench, with a 45-ft toe. Since it is usually possible to dig about 10 ft past the toe, the actual hole spacing is 30x55 ft when the holes are drilled. Ordinarily a single case (50 lb) of the special gelatin is used as the primer and the bag powder used is 20 pct. No deck charges are needed. The total charge is made up of approximately 10 pct gelatin and 90 pct bag powder. The hole is detonated by a single line of primacord.

In both areas the amount of powder per hole is calculated by the foreman, who issues written instructions to the powderman. The powderman keeps an accurate record of each hole and files his reports in the office. Single row blasting with the number of holes limited to about 10 is the regular practice. The stemming is trucked from the leaching plant and consists of leaching plant feed of —¾-in. material. This has been found to be very satisfactory. The stemming is placed in the hole directly from a dump truck through a special spout on the rear of the truck.

Secondary blasting is seldom needed. When necessary, the boulders are drilled with a jackhammer and blasted either with primacord or standard fuse and caps as the location demands. The wagon drills are used in establishing new benches where the slope of the ground prohibits the use of churn drills, also in drilling out hard toes and in road construction. Holes as deep as 30 ft are drilled using detachable bits. Blasting is ordinarily done with primacord. Compressed air for all wagon drill and jackhammer blasting is furnished by portable compressors. These compressors are also used once weekly while blowing out the motors on the shovels. Operating data for churn drilling and primary blasting are shown in Table 1.

Table 1

	Live Oak Area		Colorado Area		Combined	
	1949	1st Qtr. 1950	1949	1st Qtr. 1950	1949	1st Qtr. 1950
Ft drilled per shift	55.9	55.3	85.6	90.9	72.2	70.8
Ft drilled per CD bit	—	—	—	—	103.1	104.0
Tons broken per lb explosives	4.37	4.66	7.18	9.22	6.09	7.06

Shovel Loading

The major portion of the loading is done by two electric shovels with 4-yd dippers. These shovels have a magnetic clutch on the hoist motor. The hoist motor is driven by 2300-v, 25-cycle current. The remainder of the motors are operated on dc current. The cab is pressurized with air drawn through filters by an independent motor-driven blower.

Although these shovels will swing a 5-yd dipper, the 4-yd was chosen as the primary crusher opening will take any boulder that will pass through the dipper. Track body design also entered into the choice, four dippers full were used to fill each truck. The average truck load is approximately 24 dry tons. Loading is done on each side of the shovel, the power cable passing over a movable cable bridge under which the trucks back into loading position. This bridge is moved by raising the truck body until prongs on the truck body engage the bridge and pick it up. The truck then moves to the desired position and sets the bridge down by lowering the truck body.

Ordinarily one electric shovel is located in each pit and since both ore and waste occur on most benches, they can operate in either class of material as desired. The small diesel shovel is used only when necessary for starting benches, drop cuts, and on ore or waste when an electric shovel is not available on the bench desired. Pertinent data regarding the operation of the electric shovels is shown in Table 2.

Table 2

	1949	1st Qtr. 1950	Total to May 1, 1950
Tons per shift	5521	5644	5375
Tons per hoist cable (13 ropes)			697,206
Total tons handled No. 1 shovel			3,938,599
No. 2 shovel			5,983,271

Haulage

After considerable study a truck embodying all standard parts which would best fit conditions was designed and manufactured. This truck is powered by an engine designed to generate 240 hp at 1800 rpm. For purposes of load distribution, traction, and safety on high dumps, dual rear axles are used. The body is a rear dump, 16-cu yd struck load and is dumped by dual three stage telescopic hydraulic hoists. All tires are 14x24. With only minor changes the trucks have proven satisfactory.

Realizing that haulage costs are a major item and that by proper maintenance these costs could be kept at a minimum, definite maintenance schedules were made up and rigidly adhered to. These schedules include daily operational maintenance and service, 150 hr service, 450 hr service, and a series of planned repair jobs, all designed to keep trucks in the best of running order.

All truck repairs are noted in a log book for each truck. When items such as engines, transmissions, rear axles, and tires are changed from truck to truck, such change is noted on the file card for that item. Thus a cross index is made of all items making up the repairs and their location and length of service at any given time.

Haulage costs are broken down in two ways. First: to (1) operating (trucks only); (2) repairs (trucks only); and (3) road maintenance, with an analysis of the labor, supplies, and sundries assigned to each. Second: the repair charges are broken down to cover (1) body and hoist; (2) motors; (3) trucks, and (4) tires and tubes, with

the labor and supplies properly assigned to each item. Accurate and up-to-date information is available to the mine superintendent and the foreman on all of these items. In addition to the regular cost per ton of ore and material, truck costs are carried in cost per net-ton-mile.

Proper road maintenance and bench maintenance is of utmost importance in the life of tires and tubes. Special attention is paid to these items. All benches are kept level and clean and all grades on the haulage roads are kept to a maximum of 7 pct. The roads are being graded continually and in dry weather at least one sprinkling truck is in constant use to dampen the roads and keep down the dust. No truck is allowed to back in for loading or start up after loading until the spotter inspects the path of the wheels and removes any loose rocks that might damage a tire.

As with other items a complete record of each tire is kept in a card index. As many tires as possible were recapped, except for a few that were run to destruction for comparative purposes. Later, more tires were run to destruction. A comparison of records from start-up to May 1, 1950, is shown in Table 3.

Table 3

	No. of tires Scrapped	Avg. Miles Before Recap-ping	Avg. Total Miles
All recapped tires	102	10,870	20,342
All tires not recapped	31		16,720

The most recent study of costs per mile is in favor of not recapping. Present practice is to use care in selecting tires for recapping by careful inspection. All others will be run to near destruction before being discarded. Recapping has some intangible advantages as to traction, ease of matching tires, and saving tubes.

Engineering

The original engineering for the open-pit was done by the regular staff of mine engineers. This consisted of checking the existing undistributed surface topography and surveying and mapping the topography of the subsided areas. By using this information, together with the existing sections and information obtained by additional churn drilling, bench plans were laid out.

With the beginning of actual pit operations one pit engineer, one transitman, and one rodman were assigned exclusively to open-pit work and a branch engineering office was established at the open-pit. These men are under the supervision of the chief mine engineer. Should occasional additional help be needed, engineers or helpers are loaned from the main mine office. One statistician-clerk is employed in the open-pit office.

Two sets of bench plans were made for each bench. One set of these has the original estimate of ore and waste blocked out and calculated in tons and grade. This set of maps is used to plot all churn drill holes and their assay value, and is used in all tonnage and grade computations. The second set of maps is called the blast plan. On this set all churn drill holes are plotted, with collar elevation and depth recorded. This set is used for all blasting and digging records. Assays do not appear on these maps.

One major difference between Inspiration's open-pit and most pit operations is that part of areas are over subsided ground caused by previous underground mining, and also over abandoned underground workings. This necessitates close checking when spotting churn drill holes in order that they do not penetrate old workings. Also, cave-ins must be guarded against under roads, shovels, or other equipment. Prints of all pertinent underground maps are available in the open-pit engineer's office for checking against such dangers.

The routine day to day work of the engineering crew consists of checking and spotting all churn drill holes, giving daily shovel grade, plotting the toe lines on each active bench, and calculating the grade of each blast. The information kept on churn drill holes includes accurate spotting, measurement at time of drilling, cleanliness of bore and water level, if any. The holes are again measured just before being loaded as a check against possible caving, which would influence the loading calculations. Each churn drill is numbered and the operator is furnished metal tags to consecutively number the holes drilled by his machine. All daily information is recorded on at least one set of the master maps. Each bench, no matter how large or small, is kept to a + or — 1 ft in elevation. The toe line on active benches is plotted at least every other day.

Broken ore and waste records are kept up-to-date. All ore is sampled at the crusher and waste is grab sampled at the dump as a check against the churn drill samples. These records are checked daily by the engineers, although this data mainly is of interest to the operating department.

Road planning is of utmost importance and all roads, even short access roads, are carefully laid out as to grade and alignment. Available waste disposal areas are prospected by churn drilling for possible ore before the area is accurately contoured and an estimate made of the tonnage that can be placed in the area.

Various colored flags are used to denote specific survey lines. For example, purple flags denote toe lines; orange flags, grade; white flags, center line; red flags are reserved for blasting operations. All triangulation stations are marked with red and white pipe extensions.

The office statistician and clerk keeps a daily record of the shifts and performance of each of the various pieces of equipment. Also the prospect holes, explosive records, and tire and engine records, are compiled by this man. The entire record and mapping system for the pit is based on the assumption that it is better to have records that may not be used rather than be lacking in information of value.

The author wishes to express his appreciation to the members of Inspiration's staff who assisted in the preparation of this article.

American Mining Congress

D. D. Moffat
Gen'l. Chairman

W. M. Horne
Arrangements

F. A. Wardlaw
Reception

J. W. Wade
Reception

O. Herres
Exposition

METAL MINING

• MONDAY, AUGUST 28 •

FIRST GENERAL SESSION—*Morning.* The Business Outlook . . . Prospects for the Nonferrous Metals and for Silver . . . Trend of Metal Production, Wages and Prices . . . Problems of the Small Mine Operators.

SECOND GENERAL SESSION—*Afternoon.* Our Unmined Resources, Their Future Significance . . . Sound Currency for a Sound Economy . . . The Future of Gold . . . The Foreign Aid Program, Its Relation to the Mining Industry.

FIRST OPERATING SESSION—*Afternoon.* "Packaged" Timber Handling . . . Incentive System Increases Tons Mined Per Man Shift . . . Hydraulic Hoisting —A Unique Method of Moving Crushed Ore.

• TUESDAY, AUGUST 29 •

THIRD GENERAL SESSION—*Morning.* Domestic Supplies of Strategic Minerals . . . Progress in Stockpiling for National Security . . . Congress Reviews the Stockpile Program . . . Tariff Needs of the Mining Industry.

SECOND OPERATING SESSION—*Morning.* Operating Factors and Costs in Heavy-media Separation . . . Rod Mill Liners (panel discussion) . . . Application and Performance of New Holland Breakers . . . Golden Cycle's Modern Mill.

FOURTH GENERAL SESSION—*Afternoon.* Safety Progress in Metal Mining . . . Labor Relations Today (panel discussion) . . . The Future of Our Labor Law . . .

THIRD OPERATING SESSION—*Afternoon.* White Pine—A Potential Major Copper Producer . . . Progress Toward Production at the Blackbird Cobalt Mine . . . Geochemical Prospecting (Symposium) . . . How Aerial Photography and the Airborne Magnetometer Have Aided Extension of Ore Reserves.

L. Buchman
Publicity

E. W. Engelmann
Publicity

Mrs. L. H. Hart
Ladies

Mrs. O. N. Friendly
Ladies

H. I. Young
President

D. A. Callahan
Vice-President

A. Fletcher
Vice-President

W. J. Jenkins
Vice-President

J. D. Conover
Secretary

CONVENTION & EXPOSITION

August 28-31, State Fair Grounds, Salt Lake City

• WEDNESDAY, AUGUST 30 •

FIFTH GENERAL SESSION—*Morning.* Current proposals for Mining Law Changes—Government and Industry Views . . . The Phosphate Industry, What it Means to the West . . . The Valley Authorities Program.

FOURTH OPERATING SESSION—*Morning.* Roof Bolting in Metal Mining . . . Truck Haulage Power Plants . . . Trackless Mechanized Mining in the Lead Belt . . . Sand Filling Improves Stoping Efficiency.

SIXTH GENERAL SESSION—*Afternoon.* Atomic Energy for Peacetime Power . . . Uranium Procurement Policies and Plans . . . Economics of Domestic Uranium Production . . . Prospecting for Carnotite Deposits.

FIFTH OPERATING SESSION—*Afternoon.* Problems of Underground Rock Breaking . . . Rock Drill Developments . . . How to Get More Footage Out of Hollow Drill Steel . . . An Over-All Look at Rock Drill Bits . . . Progress in Blasting Procedures.

REGISTRATION: Advance registration is encouraged. Advance Registration cards will be sent to those who forward their names personally or through their companies. No registration fee except for representatives of non-exhibiting manufacturers. This fee is $35 for each representative, maximum of $100 for three or more.

P. H. Hunt
Trips

A. G. Mackenzie
Trips

• THURSDAY, AUGUST 31 •

SEVENTH GENERAL SESSION—*Morning.* The Mining Industry—A Case for Special Tax Consideration . . . Public Relations and Public Opinion . . . Public Relations—Importance of the Stockholder.

SIXTH OPERATING SESSION—*Morning.* The Fluosolids Process . . . Plans for Treating Greater Butte Project Ores . . . Tailings Disposal Problems . . . Grinding With Centrifuged Media.

GROUP CONFERENCES—*Afternoon.* Conferences on Taxation, Gold, Strategic Minerals, Public Lands, and other subjects.

Social Events

Welcoming Luncheon—Monday Noon. Informal luncheon in the Coliseum at the State Fair Grounds. Address by leading national figure.

"Galena Days" Celebration—Monday Night. Supper on the 6190 level at Kennecott Copper's famed open-pit operation at Bingham Canyon. Entertainment and dancing in the spirit of the old West.

Mining Jamboree—Wednesday Night. Cocktails, and a steak dinner at Lagoon, Salt Lake's big amusement park. Dancing, swimming and amusements.

Annual Banquet—Thursday Night. A "speechless" event. Entertainment program with radio and stage performers, and dancing into the AM. Informal.

Ladies Entertainment—Tuesday, a tea at the home of Mrs. C. C. Parsons; Wednesday, brunch at the Hotel Utah and an organ recital at the Tabernacle; Thursday, sightseeing tour and a picnic.

Official Program

Minerals Beneficiation Division, AIME

Regional Meeting, Salt Lake City


G. Holt, Chairman, MBD


R. Byler Chmn. Program Comm., MBD


W. Mitchell, Jr. Secy-Treas, MBD


N. Weiss Meeting Arrangements


H. R. Spedden


H. E. Ameen


J. F. Myers Honorary Chef, Scotch Breakfast


B. S. Crocker


R. I. Kingman


D. H. Gieskieng

Technical Sessions

Friday Morning, Sept. 1, 1950
Jade Room, Hotel Utah, 9 AM,
Fred C. Bond, Chairman

★ Fine Grinding in Pebble Mills at Lake Shore .... B. S. Crocker
★ Jaw Crusher Capacities—Blake and Single Toggle Types .... D. H. Gieskieng
★ The Center Peripheral Discharge Rod Mill .... D. P. Hale, Jr.
★ Preliminary Grinding Tests in a Calorimeter .... A. K. Schellinger

Friday Afternoon
Jade Room, Hotel Utah, 2 PM,
John C. Lokken, Chairman

★ An Investigation of the Amenability of the Low Grade Iron Formation of the Western Gogebic Range to Concentration .... N. M. Levine
★ Some Characteristics of Sintering and Testing Iron Ores .... F. H. Hamilton and H. E. Ameen
★ An Application of the Dutch State Mines Cyclone for Thickening and Desliming Flotation Feed .... R. I. Kingman
★ An Improved Method of Gravity Concentration in the Fine Size Range .... Arvid Thunaes and H. Rush Spedden

Social Events

★ MBD Scotch Breakfast. Thursday, Aug. 31, 7 AM
White Maple Room, Hotel Newhouse. $4.
★ MBD Luncheon. Friday, Sept. 1, 12:15 PM,
Empire Room, Hotel Utah. $5.

★ **Registration fees:** Members and nonmembers $3, Student Associates $1, Nonaffilated students $1.50.

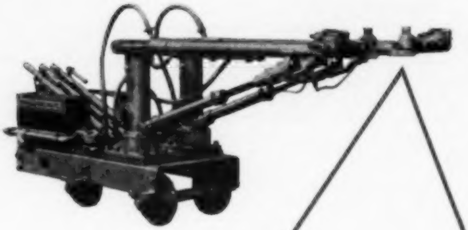
★ Registration facilities for the MBD meeting will be provided at the Fair Grounds during the American Mining Congress meeting and exposition as well as at the Hotel Utah on Sept. 1.


J. C. Lokken


A. Thunaes


F. H. Hamilton


A. K. Schellinger



Convention Exhibitors

THE exhibits of mining equipment at the AMC Metal Mining Convention and Exposition will be the largest and most diversified ever shown to the metal and nonmetallic mining industry. Over 115 leading manufacturers have been assigned a total of 36,130 net sq ft of exhibit space—49 pct more than the last such exposition. Following is a partial listing of exhibitors, the products they will show, and their representatives.

ALLIS CHALMERS MFG. CO.—Booths 401, 407. On operating Hydrocone crusher will be featured. Also on view: a Ripl-Flo screen in operation, a 3x3-in. rubber-lined pump, a 10x8-in. solids pump with automatic Texrope drive, and several motor cutaways. Photographic background for the display. **Representatives:** F. C. Bond, T. V. Canning, W. Mitchell, Jr., J. E. Dunn, F. Briber, W. A. Meyer, A. Ziehm, H. A. Wright, and A. Schlueter, all of West Allis, Wis.; B. A. Seare and J. R. Olin, Salt Lake City; D. H. Gieskieng, Denver; W. C. Kinnen, Phoenix; and H. W. Erickson, New York City.

ALLOY STEEL & METALS CO.—Booth 324-326. The new Model AB Pacific "Slushmaster" Scraper, in 26, 34, and 42-in. sizes, will be exhibited. A new Pacific Bit Knocker for knocking off single pass bits will be shown, in addition to Pacific Sheave Blocks, Sheave Anchors, and other products. J. M. McKean will be in charge.

ALBERT & J. M. ANDERSON MFG. CO.—Booth 614. POW-R-GARD and GROUND-GARD electric power distribution systems for mines will be featured. These are combinations of circuit breakers and power outlets in steel or aluminum enclosures, for safety and for efficient power distribution. **Representatives:** J. B. Luck and P. H. McNay.

AMERICAN BRATTICE CLOTH CORP.—Booth 122. ABC brattice cloth and mine vent flexible tubing will be displayed, along with sample rolls of jute brattice cloth for inspection and flame testing. The tubing will be attached to a blower which will operate intermittently.

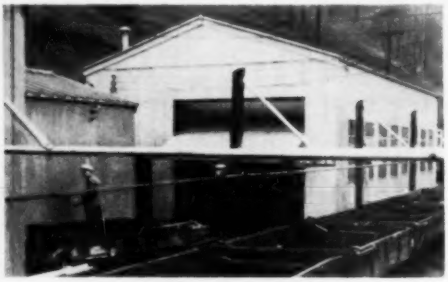
AMERICAN BRIDGE CO.—Booth 318. See United States Steel Corp. listing.

AMERICAN MANGANESE STEEL DIVISION, AMERICAN BRAKE SHOE CO.—Booth 136. A scale model in wood of a renewable lip type dipper, some manganese steel shell liners, and a complete display of hardfacing welding rods and hardfacing applications will be shown. **Representatives:** G. Ward, J. B. Terbell, H. D. Sweeney, J. T. Boisseranc, N. E. MacLean, T. C. Baker and W. C. Bruton.

AMERICAN STEEL AND WIRE CO. — Booth 318. See United States Steel Corp. listing.

CONVENTION EXHIBITORS

AMERICAN WHEELABRATOR & EQUIPMENT CORP.—Booth 616, bldg. 11. This exhibit will feature an actual size cloth bag type Dustube collector with one wall of plexiglas to permit observation of its construction. New developments in filter cloths recommended for handling dusts and fumes at elevated temperatures, as well as filter tubes that have been in operation in mining, smelting, and metallurgical fields will be available for examination. **Representatives:** R. T. Pring, G. Roper, T. M. Stanger, G. Tolton.



Armco STEELOX Building

ARMCO DRAINAGE & METAL PRODUCTS, INC.—Exhibit in an Armco STEELOX building on the Fair Grounds. Armco tunnel liner for use in entries, shafts, etc., will be shown. Other products include corrugated metal pipe, flange-type sheeting, bin-type metal retaining walls. **Representatives:** D. J. Stoker, Wm. Moss, F. Randle, B. Pitts, W. H. Spindler.

ATLAS POWDER CO.—Booth 114. Featuring latest improvements in split-second delay system of blasting, a new adjustable galvanometer, and new plastic insulation for blasting wires. **Representatives:** W. G. Frome, R. K. Gottschall, W. T. Mahood, G. W. Thompson, J. L. Romig, J. Swenehart, W. R. Wilson, E. G. Easterly, C. B. Coles, R. L. Mullen, R. M. Conner, and C. B. Prescott.

BARBER-GREENE CO.—Booth 110. Equipment will be shown in three-dimensions in color by a system of stereoscopic projection. Viewing audience will be furnished with Polaroid glasses. What are probably the first Stereo color shots of underground mining equipment in action will be featured. **Representatives:** H. W. Newton, and E. D. Stearns.

BETHLEHEM PACIFIC COAST STEEL CORP.—The company, which operates three steel plants, four fabricating works and three bolt and nut plants on the Pacific Coast, will have an exhibit featuring its steelmaking and fabricating facilities. This will be supplemented by slides showing wire rope and drill steel in use in mining operations. A guessing contest with a prize for the winner will be an attraction. **Representatives:** J. Crooks, G. M. Huck, F. T. Saunders.

BUCYRUS-ERIE CO.—Booths 611-613. Photographic presentation of the company's products. E. M. Heuston will be in charge of the exhibit.

BUDA CO., THE—Will display three new Diesel engines especially designed for haulage and mining equipment. The new 6-DA-844 Dyna-Swirl Diesel engine will be "exploded" to reveal the features of the Dyna-Swirl, controlled turbulence combustion head. Also shown will be the new models 6-DAS-844 and the 8-DAS-1125 supercharged Diesel engines. In addition, a Diesel nozzle tester and lifting jacks will be exhibited. In charge—H. H. Cohenour.

BULLARD CO., E. D.—Several new protective hats will be shown, including permanent molded colors of white, black, red, green, blue, gray and brown in the fiberglas hard boiled hats. Bullard hard boiled safety hats will also be exhibited in a new aircraft grade aluminum alloy. Other standard safety goods will be Morenci safety belts, first aid kits, protective hoods, goggles and respirators. In charge—E. W. Bullard and A. Bull.

C. S. CARD IRON WORKS CO.—Booth 605. A standard 40 cu ft rocker dump type ore car will be on display and will be representative of the complete line of this type car now available. A standard Z-20 ore car together with a rail turnout and switch stand will also be shown. Table display of rope sheaves and rollers. H. B. Patterson, representative.

CARNEGIE-ILLINOIS STEEL CO.—Booth 318. See United States Steel Corp. listing.

CATERPILLAR TRACTOR CO.—Outside exhibit between bldgs. 8 and 9. The company will show diesel wheel-type tractor with Athey Wagon, diesel track type tractor with Hyster Hystaway, diesel track type tractor with Traxcavator, diesel electric set, and diesel cutaway engine. **Representatives:** W. H. Hogan, C. E. Jones, J. M. Abbey, J. G. Findeisen, R. V. Bradley, R. D. Evans, B. R. Fitton, M. E. Fearis, T. A. Glass, E. Doubet. Also D. Robison and staff members of Robison Machinery Co.

CHICAGO PNEUMATIC TOOL CO.—Booth 723. Exhibiting the new Model G-600 drill jumbo, a rail mounted twin-boom unit for use in mine headings up to 10x12 ft. A complete line of sinker drills, demolition tools, diamond drills, stopers and CP-8 gas driven core drill will also be shown. **Representatives:** R. S. McBeth, E. R. Goss, P. G. Swanson, E. L. McLain, M. L. Tucker, L. O. Briggs, E. R. Goss, M. C. Lehmkuhl, H. P. Hansen, and G. B. Doner.

Christensen Diamond Drill Bit

CHRISTENSEN DIAMOND PRODUCTS CO.—Booth 708. Displayed will be various diamond bits, a surface drill, an underground drill, a circulating pump, and associated supplies. Core bits, casing bits, pilot bits and concave bits, as well as reaming shells of both the insert and the balanced type will be shown. Among the associated products will be core barrels, rods, foot clamps, water swivels, fishing tools, etc. W. I. Harris will be in charge.

COLORADO FUEL & IRON CORP.—Booth 700. To exhibit with its subsidiaries, the California Wire Cloth Corp., and the Wickwire Spencer Div. of C. F. & I. Central theme of the exhibit will be grinding media and samples of Cal-Wic industrial, screen, wickwire rope and mine roof support bolts. A carefully designed section of a ball mill in operation with full visibility for the spectator will be on display. **Repre-**

sentatives: H. H. Davis, in charge. Also J. T. Brittain, M. Dorward, C. E. Golson, H. M. Holkestad, D. L. Lee, G. A. Sabin, R. L. Scott, and A. S. Rairden.

COLORADO IRON WORKS CO.—The new Weinig concentrator will be featured. This gravity concentrator is designed to separate, by water medium, two ore constituents having different specific gravities. The Weinig concentrator is expected to bridge the gap between heavy density separation and flotation or other methods of separating fine sizes. In charge—H. A. Storm.

COLUMBIA STEEL CO.—Booth 318. See United States Steel Corp. listing.

CRUCIBLE STEEL CO. OF AMERICA—Booth 615. Crucible reports: "We are not going to have any equipment or steel to exhibit but we are just going to have a booth with some comfortable chairs for our visitors to sit down and rest their weary feet, and, we hope, ask us questions about hollow drill steel." **Representatives:** A. E. Perkins, in charge; R. L. Stark, W. E. Ellwanger, C. W. Darby, R. M. Simpson, G. H. Wilkinson, and R. W. Persons.

CUMMINS ENGINE CO., INC. — Three activated cutaway Cummins Diesels will be featured. These sectionalized models of lightweight, highspeed Diesel engines show the internal structure and operation of the engines including the Cummins fuel system, the new DD type fuel pump, cylinders and liners, valves, pistons, supercharger and supercharger drive, gear train, water pump, crankshaft, camshaft and the four cycle principle of operation. Internal lighting aids to clearly reveal the engine construction.

CYCLONE FENCE DIV., AMERICAN STEEL AND WIRE CO.—Booth 318. See United States Steel Corp. listing.

DART TRUCK CO.—Booth 610. The company expects to show a model of the latest in torque converter—transmission units for extra heavy mining trucks. **Representatives:** W. C. Clayton, C. F. Barber.

DENVER EQUIPMENT CO.— Will feature a four-cell No. 8 Denver "Sub-A" flotation machine concentrating a lead ore. Included in this small flotation circuit will be a Denver Agitator-Conditioner, Denver Wet Reagent Feeder and a Denver Sand Pump, operating in a closed circuit. In charge—Henry J. Gisler.

DETROIT DIESEL ENGINE DIV., GENERAL MOTORS CORP.—Booth 414. A glass-enclosed revolving cutaway of a 3-cylinder GM 2-cycle diesel engine and a torque converter model of the newly announced GM 275 hp 6-110 2-cycle engine will be shown. The elaborate revolving cutaway of the GM diesel engine has always attracted much attention at expositions. **Representatives:** R. V. Baxley, G. F. Shoemaker, H. K. McAfee, A. E. Bosetti, G. R. Holly, R. L. Burpee, M. Q. Fullington.

E. I. DU PONT DE NEMOURS & CO.—Booth 213-215. The exhibit will feature use of du Pont MS delay electric blasting caps in underground mining, and recommendations covering equipment for improving safety in blasting underground. R. H. Sumner will be in charge.

THOMAS A. EDISON, INC.—Booth 207-211. The Storage Battery Div. will exhibit batteries for both trucks and mine locomotives, highlighting features of Nickel-Iron-Alkaline storage batteries. Cutaway and animated cells and a visitor-operated display will also be included. **Representatives:** R. H. Weeks, Jr. and C. F. Holcomb.

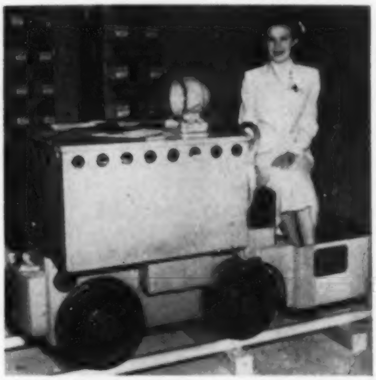
EIMCO CORP., THE—All models of underground loading equipment with air and electric motive powered models will be exhibited, including small 12B rated at 1-ton per minute to the Model 40 rated at 5 tons per minute. The newest type rocker shovel loading equipment will be featured and a full line of Eimco folding scrapers and continuous vacuum filtration equipment will be included in the display. In charge—D. W. Saunders.

EUCLID ROAD MACHINERY CO.—Booth 901. A new 10-ton model UD rear-dump Euclid truck, with double reduction planetary drive axle, and powered by a 125 hp diesel engine, will be on display. Photographs of other Euclid equipment on the job will form a backdrop for the display, and catalog literature will be available. **Representatives:** A. S. McClimon (in charge), and R. E. Keidel, F. R. Sweeney, V. L. Snow, A. W. Lehman, M. H. Johnson, E. C. Dellen, A. E. Sorensen.

FLEXIBLE STEEL LACING CO.—Booth 608. A display of belt fasteners used on conveyor belts in open-pit and underground operations will be shown. H. J. Beach will be in charge.

THE GALIGHER CO.—Booth 336. Agitair Flotation machines, Geary-Jennings samplers, ore dressing equipment, and specialized rubber-lined and rubber-covered items will be among the products shown. Metallurgists will be in attendance to explain the operation of the units in detail.

GARDNER-DENVER CO.—Booths 219, 225, 229, and 231. A great variety of equipment to be shown, including: stopers, pneumatic columns, sinker drills, airslushers, sump pumps, compressors, mine car loader, and demonstration of effect of "satinizing" rock drill parts. **Representatives:** G. V. Leece, B. C. Essig, A. W. Dale, C. J. Manley, R. S. Gibson, F. R. McNamara, L. W. Rodolf, R. R. Mayther, B. R. Sheets, O. G. Jarvis, H. Rueckert, and A. Rapp.



G-E 1½-ton storage battery trammer

GENERAL ELECTRIC CO.—Booth 315. A 1½-ton storage battery trammer locomotive will be the feature attraction. Visitors will be able to operate the 6 ft long baby locomotive. An operating, transparent plastic 10-hp Tri-Clad pump motor, with time delay switch and magnetic starter will also be shown. In addition, the G-E two-shoe magnetic d-c brake which won the 11th Annual Electrical Manufacturing Product Design Award last year will be on display. Among other exhibits will be flotation motors, contactors, battery charging sets, and GE lighting equipment. R. D. Ketner will be in charge.

GOULD STORAGE BATTERY CORP.—Booth 301. A new line of "Z" plate batteries will be shown for the first time. The positive grid on these batteries is said to

be 66 pct more resistant to deterioration, and grid porosity has been reduced 85 pct. **Representatives:** J. A. Gilruth, R. H. Carver, and C. H. Hart.

HARDINGE CO., INC.—A movie of the new Tricone Mill in operation at Tennessee Copper Co. will be key feature of the display which will include a background of lighted color transparencies and a film showing the new Hardinge Tricone Mill fabrication and operation. A film showing operation of the Hardinge Counter-Current Heavy-Media Separators on the Mesabi iron range may also be shown. In charge—G. A. Wallerstedt.

HARNISCHFEGER CORP.—Booth 513, Bldg. 11. A model P&H Magnetorque shovel will be displayed and set up for operation. A model of the P&H electric clutch as used on the company's large excavators will also be shown. An operating Zip-lift hoist will round out the exhibit. **Representatives:** P. H. Hunter, L. M. Stout, T. J. Jeanneret, A. J. Rinnander.

HERCULES MOTORS CORP.—Booths 115 and 214. Sixteen models of the complete line of gasoline and diesel engines and power units. The engines and power units exhibited are those of particular interest to mine operators. W. P. Humphrey will be in charge of the exhibit.

HERCULES POWDER CO.—Booth 100. A display of industrial explosives and blasting supplies is planned for the Hercules booth. **Representatives:** M. A. Nice, M. R. Budd, G. B. Bossert.

HEWITT-ROBINS, INC.—Booths 801, 805, 809. On display, and in operation, will be a heavy duty scalper, a unit weighing less than 6 tons able to scalp off huge rock lumps at the rate of 1100 tons or more per hr.; and an ore-type mine conveyor, a condensed version of an extra-heavy-duty mine conveyor. Also shown will be hose and belting products of the Hewitt Rubber Div., and idlers and screen cloth made by the Robins Conveyors Div.

THE HUMPHREYS INVESTMENT CO.—Booth 101. A full size Humphreys Spiral concentrator, in operation as a closed circuit, with a 10-mesh feed, will be on display. The spiral is a model 24-A 5-turn spiral, now in use in many operating plants. **Representatives:** W. E. Brown and J. V. Thompson.

INDEPENDENT PNEUMATIC TOOL CO.—Booth 232. Four completely new pneumatic mine tools will be included among the company's full line of drilling equipment. The new Thor power feed unit featuring sensitive control to eliminate carbide top drill steel breakage is the newest development to be shown. Thor sinker legs, pneumatic column and air bar feed units for drifter operation which have been introduced during the last year can be seen at the Thor booth. **Representatives:** W. A. Nugent, B. H. Johns, W. B. Hunn, M. A. Sorenson, J. F. Corkerey, and G. A. Thoma.

INGERSOLL-RAND CO.—Building 10. A large number of new products, such as rock drills, Carset jackbits, lighter drill mountings, and an improved Jackleg for mounting jackhammers. Another feature will be a new two-stage stationary compressor. Theme of the display is "From power plant to bottom of the drill hole, use I-R matched products." A hoist exhibit will include mine hoists for all purposes and a sizable portable power tool display is planned.

JEFFREY MFG. CO.—Booths 413-415-419-423-425. The following will be exhibited: mechanical vibrating conveyors, vibrating pan feeder, impact crusher (the Rock Buster), electric vibrating barrel packer, post drill, AERODYNE mine fan, Universal blower, underground belt conveyor, and belt idlers, chains and miscellaneous transmission machinery. J. H. Fulford will be in charge.

JOY MANUFACTURING CO.—Booths 333, 329, 428 and 432. New machines to be featured are the Joy 17-HR continuous-type loader, the Joy Drillmobile, S-91 stoper with telescopic feed leg, and two new portable air hoists. The complete line of Silver Streak rock drills, slushers, portable hoists, core drills, fans and blowers, air compressors, rock bits, core bits, electrical connectors and scraper buckets will be represented.

KENNAMETAL INC.—Will display rotary augur bits, together with accessories for blast hole drilling and roof bolting. Two types of rock bits will be shown, the single blade chisel type bit for uniformly hard ground and a new three point bit for average ground. Also included is a display of Kennametal tools for metal working. In charge—Richard Farris.

LE ROI CO.—Booth 300. The Cleveland Division, manufacturers of Cleveland Rock Drills, will exhibit their full line of machinery, such as the MDR mine jumbo, a patented air feed light wagon drill, and an assortment of rock drills, drifters, stopers, and reverse air feed sinker drills. An S11S short stoper, used successfully in the mine roof bolting program, will be on display. **Representatives:** R. R. Morgan, N. M. Sedgwick, R. Rodolf, W. J. Briney, and E. G. Simmons.

A. LESCHEN & SONS ROPE CO.—Booth 134. Samples of HERCULES Red Strand wire rope in the constructions generally used in mining installations will be shown, as will wire rope slings for material handling, including HERCULES Flat-Laced slings. H. L. Waltman in charge of exhibit.

LIMA SHOVEL AND CRANE DIVISION, LIMA-HAMILTON CORP.—Booth 619. A background display of full-color photographs of Limashovels, cranes, and draglines in the metal mining industry is planned.

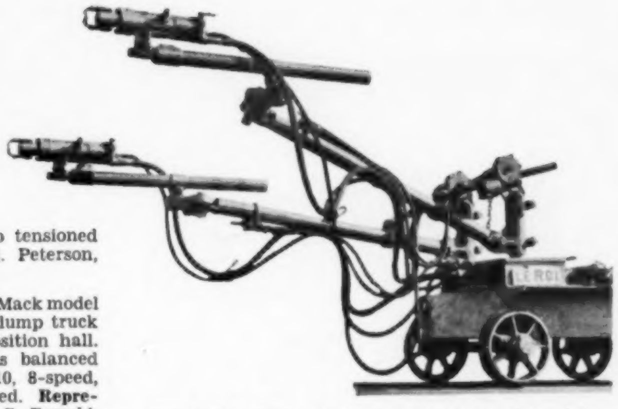
LINDE AIR PRODUCTS CO., THE—Flame-gouging, a process tailor-made for mine repair, will be featured in the exhibit. This method designed to be of material help to mine maintenance, requires only a special nozzle to convert a standard Oxweld C-32 cutting blowpipe for use in flame-gouging operations. Oxy-acetylene welding and cutting equipment for construction, maintenance and repair will also be displayed along with Oxweld, Purox and Prest-O-Weld.

LINK-BELT CO.—Booth 222. The theme of this exhibit is "Link-Belt Conveying and Processing Equipment." A backwall display of photographs will follow it up, and on the floor will be various installations such as: concentric action vibrating screen of the suspended type, belt conveyor troughing idlers, Link-Belt herringbone gear drive with the upper portion of the housing of plastic to show the internal mechanism. Ball and roller bearing pillow blocks, and other transmission units, including chains, will also be exhibited. **Representatives:** D. E. Davidson, L. O. Millard, H. V. Eastling, J. F. Strott, B. K. Hartman, H. A. Garland, W. H. Muehl, and E. H. Bugbee.

LINK-BELT SPEEDER CORP.—Booth 228. A fully operating 1-in. scale model of a Link-Belt Speeder K-375 Shovel-Crane will be working at the booth. Simulated conditions will be set up so that the model will strip overburden with a dragline attachment and dig and load ore with a shovel attachment. **Representatives:** D. W. Lehti, G. H. Olson, R. B. Barnes, D. F. Van de Roovaart, N. V. Chehak.

LUDLOW-SAYLOR WIRE CO.—Booth 126. A wide variety of actual samples of SUPER-LOY woven wire screens and wire cloths. Also samples of special hook-

Standard Le Roimine jumbo with air motors for positioning the arm. Le Roi Cleveland reverse air feed sinker drills assembled on the arm.



strip edgings for applying wire cloths to tensioned vibrator screens. **Representatives:** R. R. Peterson, J. F. Steffens.

MACK TRUCKS, INC.—Booth 501. A Giant Mack model LRSW, 30-ton, 6-wheel, off the highway dump truck will be exhibited outside the main exposition hall. Within the building Mack will show its balanced bogie and power divider. The TRDX-510, 8-speed, duplex transmission will also be exhibited. **Representatives:** P. J. Fleming, J. Walker, J. C. Rowold, S. V. Trent, and H. Weber.

MARION POWER SHOVEL CO.—Booth 125. A working, built-to-scale model of a walking dragline, which was a top attraction at last year's coal show in Cleveland, will again be on display at Salt Lake City. The model was made by a retired shovel operator who used 3000 parts and invested 6900 man hr in the task. Operated from a control board 20 ft away, the model goes through its paces in the same fashion as its big brother, the Marion 7400 walking dragline. **Representatives:** J. P. Courtwright, R. J. Lick.

MINE AND SMELTER SUPPLY CO.—Booth 128. The company will exhibit an automatic grinding circuit control called the Massco Circuitron, which is an electronic instrument to automatically maintain any grinding circuit at its optimum point by controlling the rate of new feed to the grinding mill, regulating the classifier sand load and maintaining a constant density of the classifier overflow. C. G. Willard in charge.

MSA Maskfone

MINE SAFETY APPLIANCES CO.—Booth 201. MSA will show the Edison R-4 electric cap lamp, developing 25 pct more light than previous lamps, the MSA Maskfone for communication between mask wearers, the MSA Chemox oxygen breathing apparatus, and various MSA velocity power tools for driving holes in rail and steel plate using the power of a blank cartridge. Safety hats and respirators will also be shown. **Representatives:** J. T. Ryan, C. M. Donahue, D. F. McElhattan, V. W. Buys, A. S. Abbey, E. W. Allen, J. T. Leech, H. H. McMillen, and H. D. Blanchette.

NATIONAL MALLEABLE AND STEEL CASTINGS CO.—Booth 422. In addition to displaying the well known Willson automatic couplers for mine cars, the exhibit will feature the new National NC-1 truck for mine and industrial cars, and the National rubber cushioned draft gears. Cast steel sintering pallets, sintering bars, and ore-grinding balls will also be displayed. H. H. Smith in charge.

NATIONAL TUBE CO.—Booth 318. See United States Steel Corp. listing.

NORDBERG MANUFACTURING CO.—Booth 118. Photomurals of typical installations of Nordberg machinery for processing ores and minerals and a working model of a Symons Cone Crusher will be exhibited. The Nordberg booth is designed primarily to give guests a place where they may relax and discuss their operating problems with company representatives. **Representatives:** H. M. Zoerb, H. N. Propp, G. E. Jarpe, T. E. Davis, and T. Wiedenhoefer.

OHIO BRASS CO.—Booth 334. Equipment displayed to include the new, popular O-B roof support expansion shell and plug, as well as representative safety control materials, equipment fittings, rail bonds, and collection equipment. Other material will include the O-B type T smooth underrun section insulator switch, used to sectionalize trolley or both trolley and feeder with one unit. J. H. Sanford will be in charge.

OLIN INDUSTRIES, INC.—See Western Cartridge Co. listing.

OSGOOD CO. AND GENERAL EXCAVATOR CO.—Booth 817. Large photographs and literature to be displayed. Literature will be available on Osgood and General lines, consisting of power excavators and material handlers from ⅜ cu yd to 2½ cu yd capacity, mounted on crawlers, trucks, or self-propelled pneumatic tire Mobilcranes. **Representatives:** F. L. Johnson and representatives from the Lund Machinery Co., and the Power Equipment Co. of Salt Lake City and Denver respectively.

OSMOSE WOOD PRESERVING CO.—Booth 617, bldg. 11. Samples of Osmose timber preservatives used by the mining industry, specimens of Osmose-treated mine timbers after many years of service. Photographs and technical files on all phases of mine roof support. The Osmose wooden mine roof plug will be featured. Complete cost data, plant models and descriptive literature will be available. Dan Kamphausen in charge.

PITTSBURGH GEAR CO.—Booth 701. A complete line of mining replacement parts such as gears, pinions and sprockets for loaders, cutters and locomotives will be shown. Also a Sykes continuous tooth herringbone gear and speed reducer, and a cut open Armored Gear manufactured by the company. The mining hoist manufactured by the Ottumwa Iron Works will also be on display. **Representatives:** Mr. Mervis, R. Marthens, S. Murray, and E. R. Phillips.

CONVENTION EXHIBITORS

RAYBESTOS-MANHATTAN, INC., MANHATTAN RUBBER DIVISION—Booth 130. The company will display the Homocord conveyor belt, the Ray-Man conveyor belt, the Condor Compensated transmission belt, the Condor Homoflex hose, the heavy duty Homoflex air and water hose, and the Buronik trolley wire guard. A. L. Hawk will be in charge.

JOHN A. ROEBLING'S SONS CO.—Booth 306. A comprehensive range of products will be shown, ranging from portable power and mining machine cables, bare copper, trolley contact and magnet wire, as well as wire rope for mining applications, sizing and vibrator screens, and metallic filter cloth. Eugene M. Urban in charge.

SHEFFIELD STEEL CORP.—Booth 504. An animated display featuring a revolving relief globe around which will revolve a band of grinding balls, will serve to illustrate Sheffield's exposition theme—"Sheffield Moly-Cop Grinding Balls—Used and Proved Around the World." **Representatives:** G. P. Lacy, J. E. Moeller, C. W. Hagenbuch, E. M. Gardner, A. L. Bard, C. E. Moore.

SIMPLICITY ENGINEERING CO.—Booth 237. A 4 x 14 ft model OA type horizontal double deck screen will be shown. This unit was developed strictly for the purpose of meeting low head room requirements. **Representatives:** R. R. Johnson, P. Barton, A. H. Patten, and K. Maynes.

W. O. & M. W. TALCOTT, INC.—Booth 716. The company's complete line of belt fasteners for rubber conveyor and transmission belting will be exhibited, featuring the Talcott Acme Patch Fasteners for repairing damaged or ripped belting. G. Wilson Little will be in charge.

TAMPING BAG CO.—Booth 124. Seal-tight Tamping Bags made from wet strength paper will be exhibited. Also featured will be a weed and brush killer which is a 2,4-D and 2,4,5-T base with a special aromatic petroleum emulsifier which makes it mix with water easily and which adheres to leaves for long periods. **Representatives:** A. E. Pickard, J. T. Cape.

TENNESSEE COAL, IRON & RAILROAD CO.—Booth 318. See United States Steel Corp. listing.

TRAYLOR ENGINEERING & MFG. CO.—Booth 601. Large photomurals of crushers, feeders, crushing rolls and smelting machinery made by the company will be shown. A projector will also be used to show many types of Traylor equipment in use in the field. **Representatives:** C. H. Roberts, and A. C. Mast, Jr.

TRABON ENGINEERING CORP.—Booth 612. A complete line of manual and automatic oil and grease lubrication systems will be shown, as well as mechanical and motor driven pumps. Machinery builders will have on display their equipment equipped with Trabon systems which are furnished as an integral part of the machine. **Representatives:** W. Deutsch, C. H. Spencer, and R. Nelson.

TOOL STEEL GEAR AND PINION CO.—Booth 132. A panel board containing cutaway and etched samples of specially hardened parts made for mining machinery will be on display. A few complete mining machinery parts will also be shown, and literature on tool steel products for mining machinery. **Representatives:** C. R. Burrell, J. C. Seeger, J. B. Ambler, B. H. Lyon, and L. J. Riter.

W. S. TYLER CO.—Booth 604. An operating Ty-Rock screen, such as is used throughout the world in the metal mining industry, will be featured. Samples of woven wire screens of many different metals and meshes, along with a Ro-Tap testing sieve shaker and Tyler standard screen scale testing sieves will complete the exhibit. **Representatives:** E. M. Graham, F. Braun, A. E. Reed, V. A. Kaufmann.

ULTRA-VIOLET PRODUCTS, INC.—Booth 622. A collection of colorful fluorescent minerals will be shown, in conjunction with Mineralight lamps—ultra-violet analysis lamps in both long wave and short wave models.

UNITED STATES STEEL CORP.—Booth 318. Featuring low-alloy high-strength steels, plate liners for grinding mills, aerial tramways, electrical wires and cables and wire rope. Request cards and literature will be available. R. G. Hill in charge of the staff.

VICTAULIC CO. OF AMERICA.—Booth 106. Will exhibit its world-known line of Victaulic pipe couplings, sizes ¾ in. through 60 in. in diam, and its full-flow elbows, tees, reducers and accessories for compressed air, water supply, drainage, and mill pipe systems. Units operating under air and water pressure will demonstrate Victaulic's slogan—"The Easiest Way to Make Pipe Ends Meet." **Representatives:** R. W. English, M. C. Hutchinson, H. D. Squibb, and G. McIntyre.

WESTERN CARTRIDGE CO.—(Div. of Olin Industries, Inc.) Booths 328, 329. The exhibit will show blasting caps of all kinds manufactured by Western Cartridge Co. and dynamites manufactured by Columbia Powder Co. and Equitable Powder Co. Five display units will feature the products made by the various Olin divisions. A. J. Barocca in charge.

WESTERN MACHINERY CO.—Booths 429, 437. A Wemco SH Classifier of commercial size will be displayed, arranged in operating position and wired so that booth visitors may operate the triple pitch spiral and hydraulic lifting device. Also to be shown: A commercial size Fagergren flotation machine with a special cutaway mechanism to illustrate the design of the cell, a Fagergren laboratory flotation cell to illustrate the agitation-dispersion principle of the Fagergren mechanism, a plastic model heavy media separation unit, and a Wemco centrifugal sand pump. **Representatives:** H. N. How, R. B. Utt, W. H. Reck, J. S. Huckaba, and others.

WESTINGHOUSE ELECTRIC CORP.—A special feature will be a graphic presentation of the application of type AB De-ion circuit breakers to open-pit and underground distribution systems. The display will also include: new ac and dc Life-Line motors, with a cutaway motor and splashproof unit operating under water; new Life-Linestarters; Westinghouse type BP taper-hardened steel for locomotive gears and pinions, various types of line material for underground trolley locomotive haulage, a complete line of push-button stations. **Representatives:** J. R. Fulton, R. N. Anderson.

WILLSON PRODUCTS, INC.—Booth 609. A complete line of eye and respiratory protective devices for the individual worker will be exhibited. **Representatives:** S. C. Herbine, E. A. Seares.

WORTHINGTON PUMP & MACHINERY CORP.—Booths 129 and 133. Featured in the 720 sq ft of exhibit space will be the complete line of Blue Brute drifters and stopers, Blue Brute hand held rock drills and air tools, a UMW-40 wagon drill, and representative models from the line of portable self-priming centrifugal pumps. Slides and photographs will be shown to illustrate the corporation's air conditioning and refrigerating equipment, steam turbines, electric motors, Diesel engines, and stationary compressors. **Representatives:** P. H. Nast, Jack How, J. P. MacArthur, W. H. Lehr, P. E. Wilson, C. R. Walbridge, G. H. Allen, E. D. Schively, and P. E. Alers.

Cyclone Proves Satisfactory

for Thickening, Desliming Flotation Feed

By Robert I. Kingman

Mr. Kingman is a metallurgist for National Lead Co., Tahawus, N.Y., and is a member of AIME. This is a Minerals Beneficiation Division paper and will be presented at the Salt Lake City meeting, Sept. 1.

SUFFICIENT testing has been performed with the Dutch State Mines Cyclone for thickening and desliming flotation feed at the concentrator of the National Lead Co., Tahawus, N. Y., to prove its application for this work. It is the purpose of this article to present some of the test results, operational details and advantages of cyclone thickening and classification. The metallurgy of the mill operation was described by Frank R. Milliken, assistant manager of the titanium division.[1]

The present flowsheet for the recovery of ilmenite consists in grinding the crushing plant product in four open-end rod mills in closed circuit with mechanically vibrating screens to approximately —20 mesh. The screen undersize is treated in Crockett magnetic separators which produce three products: magnetic concentrate, nonmagnetic tailing containing ilmenite and gangue, and a Crockett slime overflow. The nonmagnetic tailing is classified into eight sizer spigots products and a classifier overflow. The spigot sand products are tabled separately to produce a rough ilmenite concentrate, a middling product and a tailing. The table middlings are returned to Crockett feed. The table concentrate is dewatered and dried and further concentrated on Wetherill magnetic separators to produce the finished ilmenite concentrate.

The recovery of the fine ilmenite lost in the slime overflow products from gravity and magnetic separation is obtained by thickening and desliming these products for flotation feed. The slime overflow products from the Crockett separators, classifiers and magnetic dewaterers are fed to four 22-ft diam hydroseparators. The partially deslimed hydroseparator underflow (30 to 40 pct solids) is pump fed to two Dorr rake classifiers which accomplish further desliming to produce a classifier sand for flotation conditioning at 65 pct solids.

The total hydroseparators feed tonnage is 600 tons per day at 5 pct solids. The ilmenite slime losses in the hydro overflow reduce the underflow product to 330 tons, or a 55 pct weight recovery of the feed. Further desliming in the two rake classifiers reduces the tonnage available as flotation feed to 250 tons, which is a 45 pct weight recovery of the hydroseparator feed. The slime losses in these two operations contain the same percentage of TiO_2 as that of the recovered product, thus making the weight recovery of flotation feed the same as TiO_2 recovery. Without the excessive slime loss, ilmenite concentration by flotation was not satisfactory because of a carryover of colloidal material in the hydroseparator underflow and classifier sands.

In all testing conducted with the hydroseparator—rake classifier combination or individual use of these units, either the losses of ilmenite in the discarded colloidal fraction were excessive or the elimination of the colloids from the sand fraction was not adequate for satisfactory flotation results.

In the discussion of Retreatment of Mineral Surfaces for Froth Flotation by S. A. Falconer[2] it was expressed that most ores contain alteration products in the form of colloids or soluble salts. If these are present in appreciable amounts they may interfere with flotation and must be removed. The colloidal material and slime can

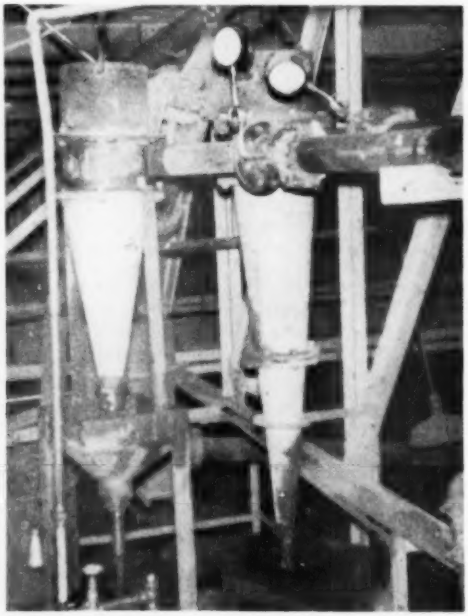
interfere in a number of ways, namely: (1) by consuming reagents, thus decreasing separating efficiency and increasing the cost of treatment, (2) by forming coatings on the other minerals and thus preventing their selective separation by flotation, or (3) by diluting the grade of the concentrate. Flocculated colloids or slimes can also interfere by enclosing fine particles of valuable mineral, preventing recovery of the latter.

With a completely dispersed feed improved classification could be obtained in the hydroseparators; however, the slightly flocculated condition of the feed (pH 8) causes the slime material to classify out with the coarser product. This is more prominent in summer months with water temperatures of 60 to 70°F. In present operation it is necessary to add underflow desliming water to make a product suitable for flotation.

In order to improve the recovery of fine ilmenite it appeared necessary to find some method of classification which would give a better separation between the harmful colloid and the floatable fraction. Various methods of classification other than the cyclone were investigated, but they were impractical because of the large volume of material to be thickened.

It was determined in the various investigative work that if efficient classification could be achieved, rejecting 15 pct of the solids in the hydroseparator feed as a colloidal product, the remaining 85 pct of the solids could be floated with satisfactory results. Thus recovery of 85 pct by weight of solids in the floatable product was the theoretical goal in testing.

With a limited amount of information available concerning the cyclone, a number of variables were first investigated with a laboratory installation. This consisted of a Wilfley pump feeding either a 3, 6, or 12-in. diam cyclone at 20 to 45 psi. The material used in testing was a part of the feed to a plant hydroseparator. The factors investigated were cone diameter, feed pressure, apex angle, area of feed inlet and overflow, and apex opening.



Plant installation of 10° and 20° 12-in. cyclones at National Lead's concentrator.

The object of the initial work with the smaller diameter cyclones was to determine from test operation if the feed product could be thickened to 65 pct solids for flotation condition, and in the same operation, if the colloidal material, detrimental to flotation and amounting to 15 to 20 pct of the total hydroseparator feed, could be rejected.

In the test procedure the efficiency of classification was measured by, (1) the percent weight recovery in the underflow and (2) results of batch laboratory flotation tests on the recovered underflow product. In all the instances the separation was adequate to produce a normal flotation concentrate and TiO_2 recovery.

The information obtained from testing with the 3 and 6-in. diameter cyclones was satisfactory from the standpoint of results in weight recovery and flotation; however, with the smaller diameter cones the capacities were limited. Some of the results in capacity, weight recovery and percent solids of the products with 3 and 6-in. cyclones are given in Table 1.

Table 1—Tests with 3 and 6-In. 10° Cyclones—Feed from Hydroseparator

Test No.	Overflow	Feed Inlet	Cone Diam. In.	Feed Pressure psi.	Feed Rate gpm	Overflow	Underflow	Pct. Wt. Recovery Underflow	Pct. TiO_2 Recovery Underflow
1	0.6	0.6	6	20	62.2	1.05	68.0	75.6	79.5
2	0.99	0.99	6	20	75.7	0.91	70.0	75.7	78.5
3	0.196	0.196	3	30	27.1	1.71	73.0	80.7	82.3
4	0.60	0.60	3	30	43.5	2.45	71.0	72.2	74.7
5	1.77	1.77	3	30	91.2	2.19	65.7	55.2	58.4

With the large volume of feed to be thickened (1600 to 2400 gpm), a considerable number of small diameter cyclones would be rquired. The initial runs with the 12-in. diam installation indicated that a weight recovery could be obtained equivalent to that of the smaller diameter cyclone and with a considerable increase in capacity. Testing with even larger feed inlet areas increased the capacity to six times that obtained with the 6-in. cyclone.

The feed pressure used in testing was that within the limits of normal centrifugal pump operations, 20 to 45 psi. All the feed rate measurements indicated the capacity to be a function of the pressure under a given set of cone conditions. The main purpose of pressure variation was to determine within what limits it could be varied, either to increase or decrease feed rate, and what the effect would be upon the weight recovery of feed. With a given number of cyclones installed, the problem encountered in mill operation of the variation in volumes of hydroseparator feed could easily be overcome by changing the feed pressure to increase or decrease feed rate. Table 2 illustrates the variations in capacity corresponding to changes in feed pressure when using the 10°—12-in. cyclone.

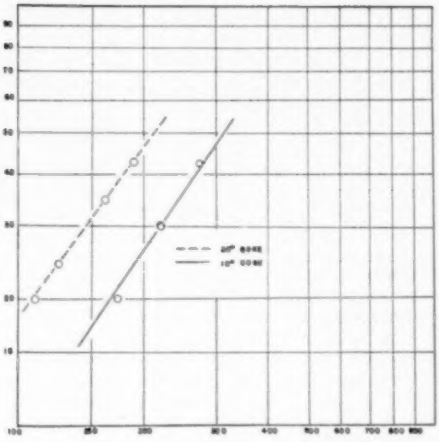


Fig. 1—Capacity effect, 12-in. 10 and 20° cyclones, other conditions constant.

Table No. 2–Effect of Pressure Variation on Capacity and Weight Recovery–10° 12-In. Cyclone–Inlet and Overflow Area 1.75 sq in.

Test No.	Feed Pressure, psi	Feed Rate gpm	Overflow	Underflow	Pct. Wt. Recovery Underflow	Pct. TiO_2 Recovery Underflow	Lb per Min. Underflow
1	20	125.0	1.80	65.8	70.2	72.8	41.4
2	25	138.0	1.41	66.7	72.4	74.7	43.7
3	30	157.9	0.98	68.0	76.4	80.7	45.2
4	35	162.9	1.16	68.2	78.2	80.7	49.2
5	44	192.2	0.87	69.4	81.9	84.5	52.2

A 5-psi change in feed pressure has no noticeable influence upon weight recovery. With the feed pressure increased from 20 to 44 psi there was a 11.7 pct improvement in weight recovery of solids and 65 pct increase in capacity.

The apex angle or the included angle of the conical section was another known variable which was examined in testing. Several runs were made with the 6-in. cyclone using either the 10 or 20° cone section. Under the same conditions of operation and with the same area of feed inlet the 10° cone showed a gain of 16 pct in capacity over the 20°. In these runs there was no noticeable difference in the weight recovery of feed.

In the pilot-plant operation of two 12-in. cyclones on the same feed, one a ten and the other a 20° cone, the 10° exhibited a 32 pct greater capacity at a given inlet area. A number of weight recovery tests indicated that the smaller angle cone gave an additional advantage of 3 pct in recovery of feed at a given rate of feed. Comparisons of the capacities of 10 and 20° cones for various feed pressures are plotted in Fig. 1.

The principal factors which influence feed rate are interdependent: cone diameter, apex angle, feed pressure, and the area of the feed inlet and overflow. For each cyclone diameter tested there was an optimum area for the feed inlet and overflow outlet. In the case of the 6-in. 10° cyclone the feed inlet and overflow openings were increased to the point where the weight recovery of feed was lowered. Table 3 illustrates the decrease in weight recovery obtained, when the feed inlet and overflow areas were increased from 1.63 to 3.14 sq in. and the capacity increased from 99 to 169 gpm.

Table 3–Effect of Inlet and Overflow Area on Weight Recovery–6-In. 10° Cyclone

Test No.	Area sq in. Overflow	Area sq in. Feed Inlet	Feed Pressure, psi	Feed Rate gpm	Pct. Solids Overflow	Pct. Solids Underflow	Pct. Wt. Recovery Underflow	Pct. TiO_2 Recovery Underflow
1	1.63	1.63	20	99.1	1.52	63.5	72.2	73.7
2	1.63	1.63	20	99.2	1.56	61.8	73.0	74.5
3	3.14	3.14	20	169.1	1.81	64.5	65.2	67.2
4	3.14	3.14	20	169.0	1.79	66.2	65.9	67.2

The most desirable arrangement was to have the feed and overflow orifice of equivalent area. Probably the most effective inlet is the rectangular cross-section with the long dimension parallel to the axis of the cone, since the feed is discharged at a minimum distance from the outer circumference of the inlet head. In Fig. 2, the feed rates are plotted for the various inlet and overflow areas used on the 12-in., 10° cyclone.

The apex or underflow outlet area is determined by the percent solids of the feed, capacity, and the desired percent solids of the discharge. In the preliminary runs with the small diameter cyclones an apex opening of fixed area was used. This type proved to be unsuitable for testing because of changes in feed solids. Test results on the basis of weight recovery were inconsistent.

The recommendations of Elliott J. Roberts of the Door Co. indicated that the fixed-apex opening was undesirable because of the build-up of thickened solids in the lower portion of the cone. This tended to cause partial short-circuiting of the feed and an unbalanced condition in which some underflow was forced into the overflow, thus lowering the percent weight recovery. The adoption of a variable rubber apex opening was found to be most advantageous for the variable feed solids. With the discharge of the underflow solids in the form of a spray, the percent solids

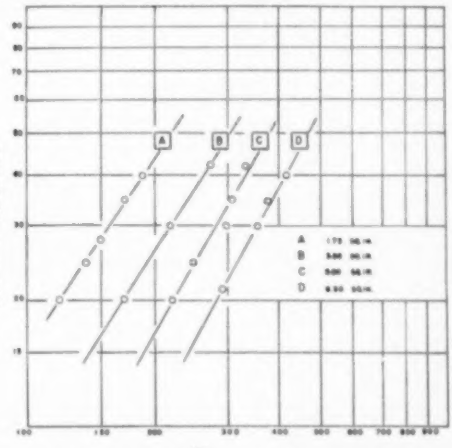


Fig. 2—Capacity effect, 12-in. 10° cyclone, with variations in the feed inlet and overflow area.

can be maintained at the desired value (60 to 70 pct) with consistent solids recovery.

The desired percent solids underflow for flotation conditioning is 65 pct; however, this is controlled between 60 and 70 pct, depending upon the tons of feed to the conditioners. Several tests were made to determine the effect on the weight recovery with the variation in cyclone underflow solids within the range of conditioning.

The four tests in Table 4, using the 12-in., 10° cyclone show no change in the weight recovery obtained at 20 and 44 psi feed pressure, with the underflow solids at the low and high limit of conditioning.

Table 4—Effect of Pct. Solids Underflow on Weight Recovery

		Gpm			Pct. Solids		
Test No.	Feed Pressure, psi	Feed	Underflow	Overflow	Underflow	Overflow	Pct. Wt. Recovery, Underflow
1	20	123.0	4.2	118.8	61.0	1.22	78.4
2	20	127.7	3.8	123.9	70.7	1.23	78.8
3	44	197.7	6.3	191.4	70.7	1.18	80.0
4	44	191.9	7.7	184.2	62.4	1.18	80.0

As previously mentioned, little consideration was given to the size separation made by the cyclone. Under the best conditions of size analysis, the size distribution of the feed to the cyclone and its products can be determined by sedimentation tests. With this method of sizing, the size of the mineral particles are determined by settling rate rather than by dimension. The variation in the specific gravity of the mineral particles of the cyclone products would tend to have their own size of classification. The higher specific gravity material recovered from the feed product would be of a finer micron size than the lower specific gravity gangue constituents.

The results of a size analysis of the cyclone products from the 12-in., 10° cyclone are given in Table 5. In the analysis of the cyclone overflow product the percentage of + 20 micron material is proportionately small. The classification size depending on particle specific gravity is between 10 and 20 micron.

Table 5—Size Analysis—Cyclone Products—12-in., 10°

	Particle Size (Pct By Weight)							
Product	+44M	20-44M	15-20M	10-15M	7-10M	5-7M	3-5M	2-3M
Cyclone Feed	33.0	23.0	10.0	11.0	6.0	4.0	6.0	7.0
Cyclone Overflow	0.0	1.0	8.0	16.0	16.0	14.0	20.0	25.0
Cyclone Underflow	44.0	30.7	10.7	9.3	4.6	0.7	0.0	0.0

The most favorable factors obtained from cyclone test procedure were used in the design of a cyclone installation for plant operation. It was necessary to gain further information on wear and operating characteristics, at continuous operation, before the entire hydroseparator feed could be treated with the cyclone. During cyclone operation the feed rates were increased further by using successively larger feed inlet and overflow areas. Table 6 shows the increase in feed rate with respect to inlet and overflow area.

The set-up for plant operation consists of two 12-in. diameter cyclones, illustrated in Fig. 3, a 12-in., 20° cast iron cone, and a 10° Ni-hard cast

Table 6—Effect of Inlet and Overflow Area on Feed Rate, 10 and 20°—12-in. Cyclone

Test No.	Overflow	Feed Inlet	Incl. Angle Cone	Pressure, psi	Rate gpm	Overflow	Underflow	Pct Wt. Recovery Underflow	Pct. TiO_2 Recovery Underflow	Lb per Min. Underflow
1	3.50	3.50	10	40	264	1.18	62.6	78.8	82.0	92.5
2	5.00	5.00	10	40	326	1.13	67.0	78.5	80.5	98.5
3	6.50	6.50	10	40	390	1.08	65.2	75.6	79.0	107.0
4	3.50	3.50	20	40	172	1.23	68.5	77.0	80.2	74.0
5	5.00	5.00	20	40	238	1.38	65.0	74.2	75.2	79.2

in two sections. The overflow products from Crockett separation, sizing and magnetite dewatering are collected by gravity and pump fed at 35 to 40 psi.

This cyclone arrangement treats 600 gpm of slime overflow (formerly hydroseparator feed at 4 to 5 pct solids. The underflow product (representative of 75 pct by weight of feed) is discharged by gravity to the flotation conditioners at a rate of 130 tons per day.

After three months of operation the most critical point of wear on the 20° cast iron cone was in the lower 25 pct of the cone section. The wear was quite uniform, consisting in the enlargement of the bottom opening of the cone, together with the wearing of shallow spiral grooves in the inner wall. Another point of wear was on the underflow side of the vortex finder near the overflow outlet. This condition was corrected to some extent by hard surfacing the vortex finder plate and by redesigning the inlet head with the top of feed inlet level with the vortex finder. The failure of the two cone sections occurred after approximately four months operation. The total amount of flotation feed thickened by the 20° cast iron section was 3300 tons while the 10° Ni-Hard cone thickened 7300 tons.

The purpose of the investigation of the cyclone was to improve recovery of fine ilmenite by thickening and desliming hydroseparator feed. It was determined that the rejection of 15 to 20 pct of the fine slime is essential for satisfactory flotation operation. The cyclone, when operated as described, produced the thickened and deslimed product which was required. Satisfactory separation of colloidal material from the flotable product could not be achieved in the hydroseparators rake classifiers because of the inefficien- of these devices as colloidal eliminators.

The addition of the cyclone separation to the present flowsheet will increase the tonnage of flotation feed from 250 to 500 tons per day, with an increase of 95 pct in the production of flotation ilmenite. Additional ilmenite produced will increase overall mill recovery of TIO_2 by 6 pct.

The author wishes to thank the National Lead Co. for permission to present this paper. Appreciation is expressed for the guidance and suggestions received from Frank R. Milliken, George W. Wunder, and Paul W. Allen; and also for assistance from John J. Strohl, Henry J. Schwellenbach, Alan Stanley, and Thomas S. MacDonald.

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A New Theory of Comminution

by Fred C. Bond and Jen-Tung Wang

Comminution energy is principally energy of deformation before breakage, which appears as heat. An empirical equation is presented which covers the entire comminution range. The new strain-energy theory considers comminution from the known principles of mechanics and the reduction ratio. Energy requirements according to the different theories are compared.

THE present status of the theory of comminution is extremely unsatisfactory. The amount of various ores and rock products crushed and ground annually approaches the staggering sum of perhaps one half billion tons. Yet the basic concepts underlying an operation of such magnitude are unknown, and actual knowledge of what takes place in comminution is almost entirely empirical.

The responsibility for this situation cannot be charged to apathy or lack of appreciation of the importance of the problem. Many attempts have been made to evolve a workable hypothesis, but none has been completely successful.

General Considerations

In order to break rock, it must be subjected to a stress which strains the rock beyond its critical breaking point. The stress imparts energy to the rock, most of which is released in the form of heat when the stress and resulting strain are removed. If the strain induced exceeds the critical strain, the energy is released by breaking; if the induced strain does not reach the critical point, the energy is released with removal of the stress as energy of resilience. Rock is a brittle material and it is assumed that it breaks approximately at its yield point, so that no permanent deformation results from strains below the critical.

When rock is broken the total energy input is accounted for by the heat liberated, and by the surface energy of the new surface produced. A small and probably negligible amount is released as noise.

Rock is commonly broken under compression and the applied stress is ordinarily compressive. However, for breakage to occur, it is only necessary that the induced strain exceed the critical value, and this strain may represent the resultant of compressive, shearing, and tensile forces. The stress-strain diagram of rocks under compression, and the modulus of elasticity as determined therefrom, should be fundamental considerations in the development of any theories of rock breakage.

Crushing in jaw or gyratory crushers results primarily from a squeezing action, and reduction in a hammer mill is the result of impact. The action in rod and ball mills is a combination of impacting, squeezing, and wearing away by attrition, or rubbing.

In ordinary crushing and grinding, the forces are applied at protruding points and are not distributed evenly throughout the rock. This is one of the features of comminution which theoretical considerations have not covered adequately. Another feature is the effect of impact velocities, which may greatly influence the total energy required for breakage. Impact velocities may vary from 1 or 2 fps in crushers to 10 or 20 fps for ball mills, and as high as 100 or more for hammer mills. However, according to the findings of geophysicists, the velocity of sound and of compression waves in stone is many times greater; the primary longitudinal compression waves travel at perhaps 15,000 fps, and the secondary transverse waves, which may reach the surface and cause cracks to form thereon, travel at perhaps 5000 fps.

When a crack tip forms, the total surrounding stresses are concentrated in this tip, which rapidly extends throughout the rock particle.[1] It would seem that the energy required to deform the rock beyond its critical strain, resulting in the formation of a crack tip, represents practically all of the energy required. Most of the primary crack tips presumably form on the surface.

A simple method of designating feed and product size is necessary for the evaluation of crushing and grinding results. Taggart's suggestion[2] that the 80 pct passing size be used has been found very practical. In this paper, the square opening screen size which 80 pct of the feed passes is designated as the feed size F, and the size which 80 pct of the product passes, or the product size, is designated as P. The reduction ratio at the 80 pct passing size, or F/P is designated as n. The feed and prod-

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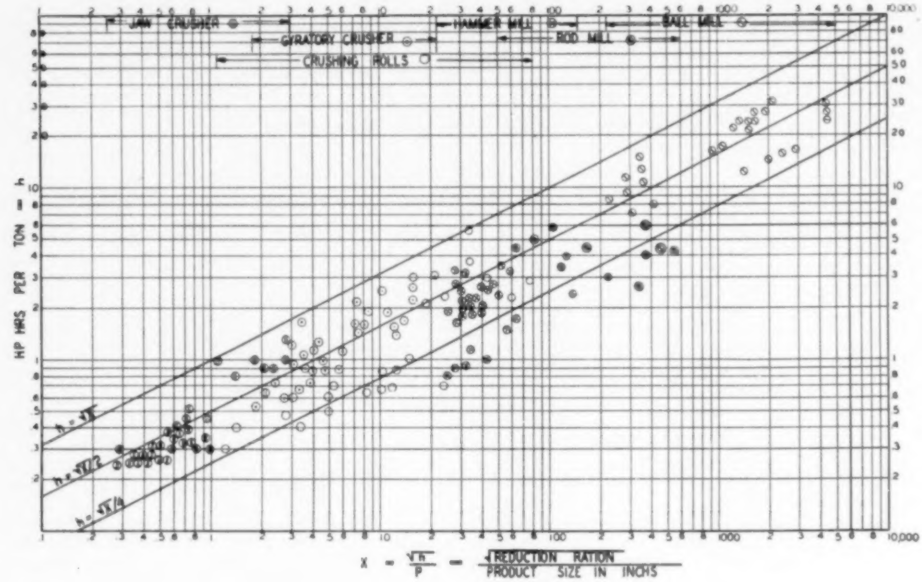

Fig. 1—Empirical energy chart.

h - hp hr per short ton (total energy input).
X - $\sqrt{n}/P$.
F - Feed size, size in inches 80 pct of feed passes.
P - product size, size in inches 80 pct of product passes.
n - reduction ratio at Product Size $= F/P$.

uct sizes are determined from the intercepts of the 80 pct passing line with the plotted size distribution and may be expressed either in inches or microns.

An Empirical Energy Chart

The energy required to crush and grind many different materials in different machines was tabulated and plotted in various manners. It was found by J. T. Wang, one of the authors of this paper, that these data could be shown consistently on a log-log plot of the energy input required in hp-hr per short ton vs. the square root of the quantity, feed size F divided by the cube of the product size P, which is equal to the square root of the reduction ratio n over P, or $\sqrt{n}/P$.

This chart is shown in fig. 1, and includes jaw crushers, gyratory crushers, crushing rolls, hammer mills, rod mills, and ball mills. It is seen from fig. 1 that the hp-hr per ton required for the average ore equals approximately one half of the term $F^{1/4}$ divided by $P^{3/4}$, which equals $0.5\sqrt{n^{1/2}/P}$. This energy is doubled for very hard stone and halved for soft material. The product size P is in inches.

The chart indicates that

$$\text{hp-hr per ton} = K_1\sqrt{n^{1/2}/P} \qquad [1]$$

where K_1 is 0.25 for soft, 0.50 for medium, and 1.00 for hard material.

This chart has been of considerable practical value in predicting approximate energy requirements. It can be used whenever the feed and product sizes are known, and an assumption can be made regarding the relative resistance of the material to comminution. The energy required for hammer mills and rolls is slightly less than the average, indicating that these machines may be relatively more efficient. The chart is entirely empirical in origin, since no comminution theory was considered in tabulating and plotting the data.

The Rittinger Theory

Over 80 years ago, Rittinger[3] stated his conclusion that the *useful work accomplished* in crushing and grinding is directly proportional to the new surface area produced, and to the reciprocals of the product particle diameters. This statement is merely a more or less arbitrary definition of useful work. However, he was evidently guided by the idea that all of the energy of crushing went into new surface,[4] and this implication is the basis of the Rittinger theory, which has been a center of controversy for many years. A. M. Gaudin[5] supports the Rittinger theory and restates it as follows: "Hence the efficiency of a comminuting operation is the ratio of the surface energy produced to the kinetic energy expended."

Energy input must be the product of force times distance, and the Rittinger theory completely ignores large variations in the distance (strain dimension or deformation) throughout which a force must act to produce breakage of different materials. The theory would perhaps have been in disrepute long ago, except for the disconcerting fact that

under certain assumptions it agrees fairly well with actual crushing and grinding results.[6, 7]

Rittinger's theory indicates that a large portion of the work done in crushing or grinding is expended on the surface areas of the very fine particles produced. The particle size distribution of the —200-mesh fractions must be known accurately in order to evaluate the theory properly. Accurate size distribution measurements below 200 mesh, or 74 microns, were rarely accomplished until recently, and at the present time measurements below 10 microns are rare and many are of doubtful validity. In order to validate Rittinger's theory, an assumption must be made below the finest sieve size, or below the limit of the finest size measured by elutriation methods. This extrapolation was made possible by Gaudin's distribution equation[8] which as later modified[9] showed that

$$Y = 100\ (x/K)^m \qquad [2]$$

where Y is the percent weight passing any diameter x, K is the diameter which 100 pct passes, and m is the slope of the log-log plot of the distribution line. This equation has been found to be approximately correct for the size distribution of any homogeneous product of crushing or grinding. It originated from study of screen analyses plots, and it has been shown later that it holds when the measured size distribution is extended down to about 13 microns by Infrasizer measurement. The probabilities are that it extends downward consistently to at least the colloidal size range. It follows a straight line log-log plot of the percent weight passing vs. the particle diameter in microns. It can be modified by replacing K in eq 2 with feed or product sizes F or P and 100 with 80.

An additional assumption is necessary before Rittinger's theory can be applied successfully, when using Gaudin's distribution equation. That is the existence of a grind limit, or a size limit above which the production of new surface area represents energy input; unless such a grind limit is assumed the total Gaudin surface area is indeterminate. It has been determined experimentally[10] that the Rittinger theory could be made to agree fairly well with the known energy inputs required in grinding if the Gaudin distribution line is extended to a grind limit of 0.7 micron, which happens to be approximately the beginning of the colloidal size range of rock. Weinig[11] had previously shown that a grind limit of one micron is probable. The surface area SA of cubical or spherical particles in square meters per 100 cc of solid can be calculated from the equation[10]

$$SA = \frac{600m}{K(1-m)}\left[\left(\frac{K}{L}\right)^{1-m} - 1\right] \qquad [3]$$

where L is the grind limit of 0.7 micron.

When a cube of height a is reduced to cubes of height a/n, the number of breaks formed in each of the three dimensions is n-1. The total number of breaks is $3(n-1)$, and the total new surface area is $6(n-1)a^2$.

If a is in inches and w equals the energy in foot-pounds required to form 1 sq in. of new surface, the total energy required to reduce the cube is $6(n-1)a^2w$. The energy h in hp-hr required to reduce one ton (2000 lb) of cubes of size a to size a/n, with specific gravity Sp, is found from

$$h = 0.1680\ (n-1)\ w\ /\ a\ Sp \qquad [4]$$

The constant 0.1680 is designated as K_r.

When the log-log plot of the percent weight passing vs. the particle size yields parallel straight lines for the feed and the product, the reduction ratio n remains constant for all sizes.

Most tests and calculations using the Rittinger theory are based upon the reduction of feed of a given particle size F to products of various sizes. However, if the product size P remains constant and the feed size varies, the theory indicates that the surface production and the energy consumption will vary as $2(n-1)/n$. If a given weight of cubes of material, each of n units size, is reduced to cubes of unit size, the new surface formed is proportional to $2(n-1)/n$. Actual measurements indicate that as the feed size increases the energy consumption increases more rapidly than the theory would indicate. This appears to be true for both crushing and grinding.

Direct measurements of the surface energy of solids have never been made. But certain indirect and possibly questionable methods indicate that the surface energy is of the order of 300 to 900 ergs per sq cm.[4] Since the actual input required is perhaps 1000 times this amount it has been frequently stated[12, 13] that the efficiency of grinding is of the order of 0.1 pct. Gross and Zimmerley[14] calculated that the net energy required to reduce quartz was 55,785 ergs per sq cm of *total* surface area produced, or about 56 joules per sq m. This is about 10 pct of the gross energy input required in commercial grinding mills to produce surface above the grind limit of 0.7 micron. A general treatment of this subject by John Gross has been published by the U. S. Bureau of Mines.[4]

If some method of comminution could be developed which would not require the expenditure of energy for deformation, which energy is liberated as heat, it might be possible to increase the mechanical efficiency as much as one thousand fold. However, as long as deformation is required for crushing and grinding, it is somewhat misleading to speak of efficiencies of 0.1 pct.

The Kick Theory

More than 60 years ago, Friedrich Kick calculated[15] from a consideration of the stress-strain diagram that the energy required in comminution is independent of the feed or product size, and depends only upon the reduction ratio. The theory has been stated variously as: (1) "the energy required for producing analogous changes of configuration of geometrically similar bodies of equal technological state varies as the volumes or weights of the bodies"; and (2) "For any unit weight of ore particles the energy required to produce any desired reduction in volume of all the particles in the mass is constant no matter what may be the original size of the particle."

An original mathematical treatment of Kick's theory is as follows:

Let K_k represent the energy in hp-hr per ton required to reduce one ton of stones of size a to size $a/2$. This represents one reduction step, and r steps are required for reduction to size a/n. It follows that the reduction ratio n equals 2^r, and r equals log n divided by log 2.

The total energy required is the sum of that required for each step. In the first step, size a is reduced to $a/2$, and in the second step size $a/2$ is reduced to $a/4$. In the final step, $a/2^{r-1}$ is reduced to $a/2^r$. In each ton there are 2^3 times the number

of particles that were present in the preceding reduction step. Therefore, the total energy h required for reduction is

$$h = K_s + 2^3K_s(1/2)^3 + K_s4^3(1/4)^3 + \dots K_s(2^{r-1})^3(1/2^{r-1})^3 = rK_s = K_s(\log n/\log 2) \quad [5]$$

Eq 5 shows that according to Kick's theory the energy required for each reduction step varies directly as log n divided by log 2, and is independent of the feed size.

H. Stadler[10, 11] vigorously supported Kick's theory and condemned that of Rittinger. From the stress-strain diagram, he derived a scale of ordinal energy units proportional to the energy input required according to Kick's theory. These Stadler ordinal numbers equal —10 times the log of mesh aperature in inches, and are proportional to log n/log 2. However, his illustrations of the agreement of the theory with the actual energy input required in crushing and grinding are not conclusive.

A complete mathematical exposition of Kick's theory was published by Taggart.[7]

The Strain Energy Theory

This theory was evolved by Jen-Tung Wang and is presented here for the first time. It was derived from a mathematical consideration of the forces and energy involved in the deformation of elastic materials.

It is assumed that the stone particles before and after crushing take the shape of cubes, just as was done in analyzing the energy per ton of stone crushed using Rittinger's and Kick's theories.

Let a equal initial size of stone in inches,
n equal reduction ratio, or F/P,
Sp equal specific gravity of the material,
S equal ultimate compressive strength of stone in pounds per square inch,
E equal Young's Modulus in pounds per square inch.

Then the force required to crush equals Sa^2.

For the purpose of this analysis, it is considered that the reduction of the stone particles from size a to size a/n, under compression parallel to the X axis, takes the following steps:

1. First consider a break perpendicular to the X axis dividing the stone into two pieces with thicknesses in the X direction equal to $(a)(n\text{-}1)/n$ and a/n respectively.

In this action:

$$\begin{aligned} \text{Force} &= Sa^2 \\ \text{Unit strain} &= S/E \\ \text{Total strain} &= Sa/E \end{aligned}$$

The total energy of resilience equals one half force times strain, or 1/2 times Sa^2 times Sa/E, or $S^2a^3/2E$.

2. The next step is dividing the piece with thickness $(a)(n\text{-}1)/n$ into two pieces of thickness $(a)(n\text{-}2)/n$ and a/n. The slabs that have been already reduced to a thickness a/n in the X direction need no more reduction in this particular direction.

In this step:

$$\begin{aligned} \text{Force} &= Sa^2 \\ \text{Unit strain} &= S/E \\ \text{Total strain} &= (S/E)[(n\text{-}1)/n](a) \\ \text{Total energy} &= (S^2a^3/2E)[(n\text{-}1)/n] \end{aligned}$$

3. The action is continued until all the slabs have thickness a/n in the X direction. It will take altogether $(n\text{-}1)$ steps. The total energy (U_x) required in this process of reduction in the X direction is:

$$\begin{aligned} U_x &= \frac{S^2a^3}{2E} + \frac{S^2a^3}{2E}\left(\frac{n-1}{n}\right) + \frac{S^2a^3}{2E}\left(\frac{n-2}{n}\right) + \dots \frac{S^2a^3}{2E}\left(\frac{2}{n}\right) \\ &= \frac{S^2a^3}{2En}\left[n + (n\text{-}1) + (n\text{-}2) + \dots 2\right] \\ &= \frac{S^2a^3}{2En}\left[(n\text{-}0) + (n\text{-}1) + (n\text{-}2) + \dots \{n-(n\text{-}2)\}\right] \\ &= \frac{S^2a^3}{2En}\left[n\,(n\text{-}1) - \{0 + 1 + 2 + \dots (n\text{-}2)\}\right] \\ &= \frac{S^2a^3}{2E}\left[(n\text{-}1) - \frac{\tfrac{1}{2}(0 + n\text{-}2)\,(n\text{-}1)}{n}\right] \\ &= \frac{S^2a^3}{2E}\left[(n\text{-}1) - \frac{(n\text{-}1)\,(n\text{-}2)}{2n}\right] \\ &= \frac{S^2a^3}{2E}\left(\frac{n-1}{n}\right)\left[n - \frac{n-2}{2}\right] \\ &= \frac{S^2a^3}{4E}\,\frac{(n\text{-}1)\,(n+2)}{n} \end{aligned}$$

A similar amount of energy is required to break into seams perpendicular to each of the Y and Z directions.

Therefore, the total energy U_y equals U_z equals U_x, and

$$\Sigma U \text{ equals } \frac{3S^2a^3}{4E} \cdot \frac{(n+2)\,(n\text{-}1)}{n} \text{ for each cube.}$$

It follows that the energy h in hp-hr per short ton required to crush is

$$h = \left[\frac{0.001748\,S^2}{SpE}\right]\left[\frac{(n+2)\,(n\text{-}1)}{n}\right] \quad [6]$$

The constant 0.001748 is designated as K_e.

According to both Kick's theory, eq 5, and the strain energy theory, eq 6, the energy required for comminution is independent of the particle size concerned, and is a function of the reduction ratio n. According to Kick's theory it is proportional to log n/log 2, while according to the strain energy theory it is proportional to $(n+2)\,(n\text{-}1)\,/n$, or almost directly proportional to n. As the reduction ratio increases, the energy required for comminu-

Table I. Energy Units Required

n Reduction Ratio of Unit Cube (a = 1) (P = 1/n)	No. of Cubes Formed (n^3)	Rittinger New Surface Theoretical (n — 1)	Kick $\frac{\log n}{\log 2}$	Strain Energy $\frac{(n+2)\,(n-1)}{n}$	Empirical Eq 1 $\frac{n^{1/4}}{\sqrt{P}} = n^{3/4}$
1	1	0	0	0	0
2	8	1	1	1	1
3	27	2	1.584	1.67	1.355
4	64	3	2.000	2.25	1.682
5	125	4	2.320	2.80	1.986
6	216	5	2.584	3.33	2.280
7	343	6	2.808	3.85	2.558
8	512	7	3.000	4.37	2.828
1	1	0	0	0	0
2	8	0.143	0.333	0.229	0.354
3	27	0.286	0.528	0.382	0.479
4	64	0.428	0.666	0.515	0.595
5	125	0.572	0.773	0.641	0.702
6	216	0.714	0.861	0.763	0.807
7	343	0.857	0.936	0.882	0.905
8	512	1	1	1	1

tion increases much more rapidly according to the strain energy theory than it does according to Kick's theory. The derivation of Kick's theory is based upon a stage by stage reduction, while the strain energy theory is based upon a generalized reduction ratio of any value. The strain energy theory assigns a greater proportion of the total energy input to the fine size reductions than Kick's theory, and thus appears to fit the facts more closely.

The strain energy theory indicates that the energy required for crushing varies inversely as the modulus of elasticity and specific gravity, and directly as the square of the compressive strength and as the approximate reduction ratio.

The accuracy of extrapolation below the finest measured particle size affects the Rittinger results much more than it does the Kick or strain energy results.

A Modified Rittinger Method

It has been shown that if the feed size F remains constant, the energy required according to Rittinger's theory varies inversely as the product size P. It also can be shown, according to Rittinger's theory, that if the product size remains constant and the feed size varies, the energy for a constant volume of feed will vary as $2\ (n\text{-}1)\ /n$. Combining these expressions shows that when both feed and product size vary the energy h required in hp-hr per ton should be proportional to $2(n\text{-}1)\ /Pn$.

If K_7 represents the hp-hr required to reduce one ton of 1-in. cubes to ½-in. cubes the energy required is

$$h = K_7\ (n\text{-}1)\ /Pn \qquad [7]$$

The constant K_7 should be numerically equal to the K_5 used in Kick's theory if the comminution efficiencies are equal.

The above expression assumes that the slopes of the feed and product distribution lines are equal and does not give the same results as Rittinger's theory, when the surface areas of the feed and product are calculated directly with a slope of 0.7 and a grind limit of 0.7 micron; it is designated here as the modified Rittinger method.

Separate Size Fraction Calculations

If the size distribution data are sufficiently complete, the energy required to reduce each size fraction separately can be calculated, using the plotted distribution line only for extrapolation below the finest size determination. It is assumed in this calculation that the largest size fraction of the feed goes into the largest size or sizes in the product. This is not necessarily true in actual crushing and grinding operations, but with a homogeneous material the statistical effect should be the same, and the reduction ratio of each size fraction is determined on this basis. When the standard $\sqrt{2}$ screen scale is used, the reduction ratio n for any size equals $\sqrt{2}$ to the exponent of the number of screen intervals between the feed and product sizes. The relative energy for each size fraction can be calculated for any comminution theory, using the appropriate function of the reduction ratio and feed or product size, and the summation of these values should be somewhat more accurate than the calculations in which a straight line size distribution is assumed. The particle size used for each fraction is the average between the retaining sieve opening and the next larger seive through which it has passed.

That portion of the product which passes the finest testing sieve is considered to have the same reduction ratio as the lower half of the sized material.

This method is particularly applicable where the feed is scalped, or has undersize removed by screening, since in this case the log-log plot of the distribution line is not straight.

Comparison of Theories

Table I has been computed to show the relationship of the different theories for different reduction ratios of one cube of unit size ($a = 1$ in.). In the first half of the table, the relative energy requirements are calculated for reduction ratios of 1 to 8, inclusive, on the assumption that one unit of energy is required in all theories for a reduction ratio of 2. In the second half of the table, it is assumed that one energy unit is required in all theories for a reduction ratio of 8.

The theoretical Rittinger new surface and the modified Rittinger method have the same values in table I. However, the total energy required for reduction of a unit weight with a constant reduction ratio increases as the feed or product size decreases, according to the Rittinger theories and the empiri-

Table II. Critical Strain Necessary to Break Nine Varieties of Rock

Rock	Moduli/1,000,000						
	E Stress/Strain	G Rigidity	K Bulk	σ Poisson's Ratio	S Compressive Strength (Crit. Stress)	Q S/E (Critical Strain)	C Impact Crushing Strength
Quartzite	9.520	4.275	4.110	0.112	28,730	3.018	
Syenite	10.420	4.280	6.170	0.218	27,890	2.676	
Diabase and gabbro	13.030	5.390	7.490	0.207	25,610	1.966	20.11
Gneiss	10.520	4.765	4.440	0.104	22,190	2.109	
Granite	6.460	2.764	3.235	0.168	21,050	3.260	14.67
Slate	11.520	5.190	4.925	0.110	21,050	1.827	
Marble	6.380	2.657	3.540	0.200	14,500	2.272	
Limestone	9.030	3.680	5.490	0.227	13,660	1.513	11.45
Sandstone	7.540	3.215	3.980	0.172	10,530	1.396	
Average	9.380	4.010	4.715	0.169	20,579	2.227	15.41

All three moduli values (E, G, and K), and the compressive strength (S) are given in pounds per square inch.
The critical strain (Q) is given in thousandths of an inch per inch of length.

The impact crushing strength (C) is the breaking strength in foot-pounds per inch of thickness, measured on the rock types tested in the Allis-Chalmers Laboratory.

$$G = \frac{E}{2(\sigma + 1)} \qquad K = \frac{1}{\frac{9}{E} - \frac{3}{G}}$$

Table III. Grinding and Crushing Data

Pct Passing	Grinding		Crushing	
	Feed	Product	Feed	Product
1 + ½ in.			100.0	
1	100.0		70.0	
¾	96.0		22.0	
½	93.2		7.5	
⅜	90.2	100.0	4.0	
3 mesh	83.0	99.0		100
4	72.3	98.0		91
6	59.6	97.0		72
8	43.0	96.5		57
10	31.5	95.9		48
14	23.0	94.0		38
20	16.6	91.7		30
28	12.5	86.9		23
35	9.6	76.0		18
48	8.2	67.3		15
65	6.6	58.5		12
100	5.1	50.0		10
150	3.3	40.0		8
200	2.2	31.8		6.5

cal equation, while it is independent of the size according to the Kick and strain energy theories.

Fig. 2 shows the relationship between the empirical eq 1 of fig. 1 for hard, medium, and soft stone; and the various theories for material of medium hardness. The material was assumed to be the average material shown in table II, with a modulus of elasticity E of 9,380,000 psi, an ultimate compressive strength of 20,579 psi, a critical strain of 0.002227 in. per in., a specific gravity of 2.65, a distribution line slope of 0.7, and a grind limit of 0.7 micron. Two feed sizes a were considered: (1) 50 cm or 19.69 in., and (2) 2 cm or 0.788 in., corresponding roughly to primary crushing and grinding respectively. Intermediate feed sizes should give lines lying between those shown, resulting in a family of curves for each theory. A sufficient number or reduction ratios were calculated to determine the position and curvature of both lines according to each theory.

It was assumed in all cases that the minimum breakage which would completely relieve the compressive stress on a cube is one break across the center of the cube parallel to each of the XYZ planes, which corresponds to a reduction ratio n of 2. An inch cube of the above material broken in this manner requires

(3) (20,579) (0.002227)/(2) (12), or 5.724 ft-lb. One ton contains 20,900 cubes, and requires 119,700 ft-lb, or 0.06045 hp-hr.

A cube of 1 in. forms 6 sq in. of new surface, so that the surface production energy w is 0.954 ft-lb per sq in., 2004 joules per sq m, or 2,004,000 ergs per sq cm.

Substituting in eq 1 gives

$$0.06045 = K_1\sqrt{2^{1/2}/0.5}$$

from which K_1 equals 0.036 hp-hr per ton. Since the actual energy required for average material shows K_1 equal to 0.5, the indicated efficiency of comminution with the above assumptions is 7.2 pct, according to the empirical chart.

The Rittinger new surface areas were computed from eq 3, and the surface production energy w was converted to hp-hr per ton and plotted. It is seen that the Rittinger curves indicate a higher energy consumption than actually is required. The Rittinger primary crushing curve for average material is close to the actual energy required for hard material, and the Rittinger grinding curve is the highest curve on the chart. If the Rittinger theory is correct the mechanical efficiency of crushing is less than that of grinding. As the reduction ratio decreases below 3 the indicated energy required drops off more rapidly than the actual energy.

It should be emphasized that these curves are entirely dependent upon the grind limit of 0.7 micron, which was derived years ago from a completely different approach.[10]

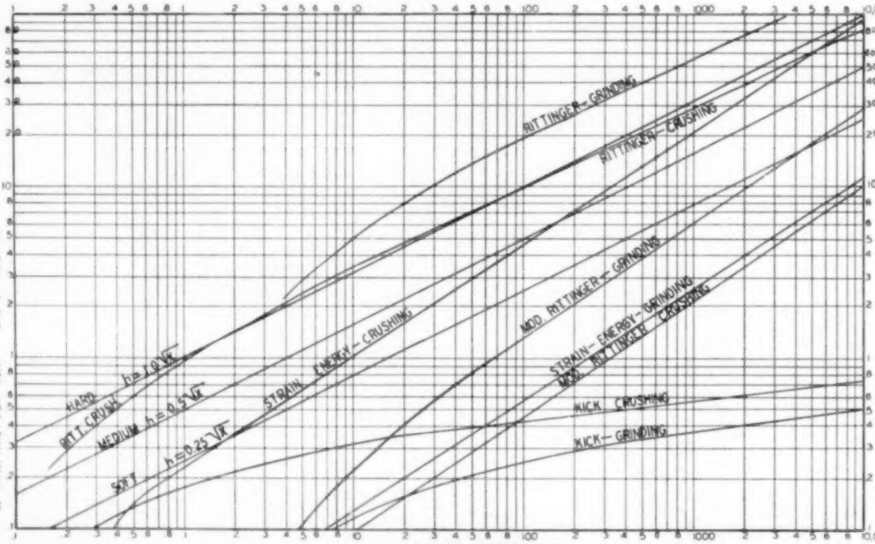

Fig. 2—Theoretical and empirical energy.

The Kick curves were computed from eq 5, with K_5 equal to 0.06045 hp-hr per ton. The Kick energy is very much less than the actual energy, and is relatively low for grinding and high for crushing, the slope of the curves being much less. The 50-cm feed requires more energy than the 2-cm feed. The Kick curves correspond very poorly with actual energy requirements.

The strain energy curves were computed from eq 6. The term 0.001748 $S^2/(E)$ (Sp) has the value of 0.0297. The curves are somewhat steeper than the actual energy requirements, and the primary crushing requires much more energy than the grinding. The primary crushing curve corresponds with the actual energy requirements more closely than any other theoretical curve; however, as the feed size decreases the indicated mechanical efficiency decreases rapidly. The plot shows that if the strain energy theory is correct, crushing is a more efficient operation than grinding in tumbling mills; this appears reasonable because of the mechanical action in the machines. The true relative efficiencies of crushing and grinding cannot be determined until one comminution theory is accepted as correct.

The modified Rittinger values were computed from eq 7, in which the constant K_7 has the value 0.06045. The product size P is in inches. The curves are roughly parallel to the strain energy curves. However, the primary crushing requires less energy than the grinding, and crushing is less efficient than grinding. Mechanical efficiency is lower than in the strain energy theory.

Table II has been prepared from the averages of published values.[10] It lists the critical strain, in thousandths of an inch per inch of thickness, required to break nine different classes of stone and the compressive strength or critical stresses of these stones. It is seen that the modulus of elasticity E, the modulus of rigidity or shear modulus G, and the bulk modulus or reciprocal of compressibility K all tend to decrease with the compressive strength although the correspondence is not close. Poisson's ratio (σ) appears to be independent of the compressive strength. More accurate determinations of the modulus of elasticity are necessary for the proper application of the strain energy theory. The large variations in the critical strain values show the large possible errors resulting from the Rittinger theory in which the strain is not considered.

Examples of Calculations

Operating data from a typical grinding and a typical crushing installation have been analyzed according to the different theories.

Grinding: Portland cement clinker was ground dry at the rate of 75 short tons per hour in open circuit in a preliminator ball mill 10 ft in diam by 11 ft 1 in. long inside, running at 17.9 rpm, with a ball charge of 110,000 lb.

The average temperature of the feed was 90°F, and the product was 145°F. Assuming a 10 pct radiation loss, and a specific heat of 0.221, all of the 10.6 hp-hr per ton energy input required to grind is accounted for as heat produced.

Crushing: Limestone scalped at ¼ in. was crushed in open circuit in a gyratory crusher.

Table V exemplifies the separate size fraction calculations used in the grinding section of tables III and IV.

Table IV. Grinding and Crushing Data

	Grinding	Crushing
Material	Clinker	Limestone
Total hp-hr per ton, h	10.6	2.27
Specific gravity, Sp	3.15	2.60
Comp. strength, S	12,000	11,000
Modulus, E	5×10^6	7×10^6
Crit. strain, Q	0.0024 in.	0.00158 in.
Feed size, F	0.228 in.	1.14 in.
Product size, P	0.0185 in.	0.15 in.
Reduction ratio, n	12.3	7.6
Constant, K_1	0.77	0.53
Rittinger calculations		
Eq 3		
Feed, m	0.840	3.1
K	6,400	30,000
SA	1.6	0.03
Prod., m	0.640	0.64
K	440	5,400
SA	22.2	4.80
New surface	20.6	4.77
Joules per gram	31.4	6.72
Joules per sq m	480	366
Ft. lb per sq in., w	0.228	0.1745
Eq 4, h	0.603	0.0653
Ft. lb to break in. cube		
In mill (6 sq in.)	1.368	1.046
By compression	1.20	0.724
Pct efficiency	87.8	69.4
Kick calculations		
Eq 5, K_5	2.83	0.776
Ft. lb to break in. cube		
In mill	330	72
By compression	1.20	0.724
Pct efficiency	0.36	1.00
Strain energy calculations		
Eq 6, h	0.210	0.097
Pct eff. (h per actual hp-hr per ton)	1.98	4.27
Separate size calculations[a]		
Avg. $(n+2)$ $(n-1)$ $/h$	16.193	27.32
Eq 6, h	0.259	0.318
Pct eff. (h per actual hp-hr pr ton)	2.44	14.0
Modified Rittinger calculations		
Eq 7, K_7	0.94	0.392
Ft. lb to break in. cube		
In mill	[illegible]06	36.4
By compression	1.20	0.724
Pct efficiency	1.13	1.99

[a] These calculations were made from the screen analyses as described in the text under the heading "Separate Size Fraction Calculations". They result in more accurate values of h, particularly when the feed is scalped.

Table V. Separate Size Fraction Calculations

Feed	Product	Screen Intervals	Percent Reduced	Reduction Ratio (n)	Strain Energy $(n+2)$ $(n-1)$ $/n$	Col. 4 Times Col. 6
1 in.	⅜ in.	3	0	2.83	3.12	0
¾ in.	3 mesh	3	1.0	2.83	3.12	3.12
	4	4	1.0	4.00	4.50	4.50
	6	5	1.0	5.66	6.30	6.30
	8	6	0.5	8.00	8.75	4.37
	10	7	0.5	11.31	12.14	6.07
½ in.	10	6	0.1	8.00	8.75	0.87
	14	7	1.9	11.31	12.14	23.06
	20	8	0.8	16.00	16.87	13.50
⅜ in.	20	7	1.5	11.31	12.14	18.22
	28	8	1.5	16.00	16.87	25.31
3 mesh	28	7	3.3	11.31	12.14	40.60
	35	8	3.9	16.00	16.87	65.80
4	35	7	7.0	11.31	12.14	85.00
	48	8	3.7	16.00	16.87	62.40
6	48	7	5.0	11.31	12.14	60.70
	65	8	7.7	16.00	16.87	130.00
8	65	7	1.1	11.31	12.14	13.36
	100	8	8.5	16.00	16.87	143.50
	150	9	7.0	22.62	23.52	164.60
10	150	8	3.0	16.00	16.87	50.60
	200	9	8.2	22.62	23.52	192.90
Sum			68.2			1,114.80
	−200	7.82 (avg.)	31.8	(15.00)	915.87	504.50
					Total	1,619.30

Summary and Conclusions

As empirical equation for the total energy input required in crushing and grinding has been derived. The energy in hp-hr per short ton of average material equals one half the square root of the term —reduction ratio to the one half power divided by the product size in inches. This energy is doubled

for very hard materials and halved for very soft materials. The product size is the size which 80 pct of the product passes. The approximate energy input required for any crushing or grinding installation can be calculated from this equation.

Practically all of the energy required is energy of resilience, which deforms the rock beyond its elastic limit, and is released as heat after breaking or release; the amount absorbed as increased surface energy is negligible. There is no known way of breaking rock without first deforming it beyond its elastic limit, excepting fatigue failures. The deformation or critical strain at breakage varies widely for different materials.

The mechanical efficiency of comminution might be defined as the percentage of the total energy input that results in deformation beyond the critical strain and consequent breakage. Contacts which cause deformation below the critical strain are wasted except as they result in fatigue breaks.

A new theory of comminution has been developed called the strain energy theory. According to this theory, the energy required varies directly as $(n+2)(n-1)/n$, where n is the reduction ratio and is independent of the feed or product size. It also varies directly as the square of the compressive strength, and inversely as the modulus of elasticity. In primary crushing, it apparently agrees with actual energy requirements better than any other theory, and indicates that crushing installations are more efficient than grinding, which appears reasonable.

There are two mutually contradictory methods of measuring the work done in comminution. In one method, the work is dependent upon the reduction ratio as calculated by the strain energy and Kick theories. These theories have a mathematical background, and the strain energy theory as applied to cubes can be adapted from the known principles of mechanics and the strength of materials. The energy required to break cubes of cement clinker and limestone, according to the strain energy theory, ranged from 2 to 14 pct of the actual energy required to grind or crush. The reduction ratio at the sizes which 80 pct of the feed and product pass is usually sufficiently accurate to serve as a measure of the work done if the log-log plots of the feed and product distribution lines are approximately parallel. However, if the feed has had the fines removed by screening, the weighted reduction ratio should be calculated over the entire size distribution range. The Kick theory was derived from a consideration of stage reductions and indicates lower efficiencies than the strain energy theory.

In the other method, the work done is measured by the new surface area produced, as first proposed by Rittinger, and later defined by Gaudin as, ". . . the efficiency of a comminuting operation is the ratio of the surface energy produced to the kinetic energy expended."[19] This theory cannot be justified mathematically, since work is the product of force times distance, and the distance factor is ignored. In two examples listed, the energy required for the initial break of cubes showed the comminution efficiency to be 88 pct and 68 pct. The energy input required per unit of new surface area produced is called surface production energy, and averages perhaps one thousand times the true surface energy. It is principally the energy required for deformation to beyond the critical breaking strain, which is liberated as heat.

The correct theory will not necessarily correspond with the empirical eq 1, since the latter may include wide variations in the present operating efficiencies of reducing large and small particles.

The strain energy theory was evolved to provide a working formula, which would apply over the entire crushing and grinding range and would have a rigorous mathematical background based upon mechanics. Although the Kick theory has such a background, it obviously assigns too large a portion of the total energy input to reduction of the largest particles. The Rittinger theory is not tenable from the viewpoint of mechanics and has been criticized as assigning too much energy to reduction of the very fine particles, while requiring the use of a more or less arbitrary grind limit. Between the two extremes, the strain energy theory appears to form a rationalization which may lead ultimately to a more satisfactory concept of the theory of crushing and grinding.

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An Improved Method of Gravity Concentration in the Fine-Size Range

by Arvid Thunaes and H. Rush Spedden

Pilot plant test work in 1942 and 1943 showed that by a combination of desliming, fine-size classification, and Sullivan deck concentration it is possible to recover heavy minerals such as cassiterite at least as fine as 10 microns in size. This appreciable improvement in gravity concentration practice has been substantiated by several full-sized plants.

IN the past, mills treating ores of tin and tungsten by gravity concentration have recovered very little mineral finer than 325 mesh, although some form of slime concentration has been generally attempted by the use of buddles or round tables. This paper describes a series of pilot plant tests made in 1942 and 1943 in which the use of the Sullivan deck was investigated for the recovery of an appreciable amount of the fine values formerly lost.

The investigation was initiated by the U. S. Government in an effort to increase the wartime production of tin. Bolivian milling practice at that time included jigging of the coarse sizes, tabling of the intermediate sizes on conventional shaking tables, and the use of buddles or round tables on the finest sizes. Flotation of the pyrite was employed at different stages of the treatment, depending upon the quantity present and the preference of the operator. Usually good recoveries and the bulk of the production were made in the jigging and tabling operations provided that these sections were not overloaded. Buddles and round tables were used for a small additional recovery if it could be shown that they could pay for their high cost of operation.

Extensive test work established that by a combination of desliming, classification, and Sullivan deck treatment, cassiterite as fine as 10 microns (1500 mesh) could be recovered when proper conditions were maintained. This test work has been verified by several full-scale installations. The method is generally applicable to the preconcentration of large tonnages of low-grade ores or tailings for the recovery of a small amount of a valuable heavy mineral.

The Sullivan deck (or now the Denver Buckman tilting concentrator), which is the essential part of the method, was devised originally for the recovery of tin from tailings of the Sullivan concentrator, Kimberly, B. C. Since the material treated contained only 0.05 pct Sn, it was impractical to attempt to recover cassiterite finer than 500 mesh.*

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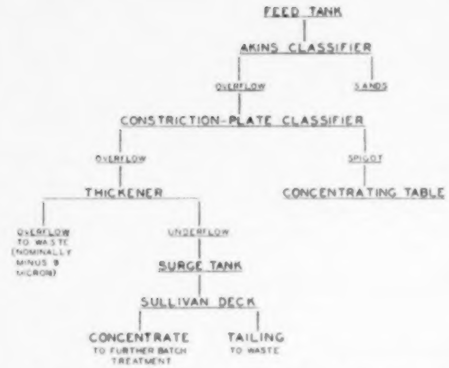

Fig. 1—Flowsheet for pilot plant of 5-ton per day capacity.

The work reported herein is thus an extension of the original application.

Test Work, Catavi Mill

The largest and most important producer in Bolivia is the Catavi mill of Patiño Mines and Enterprises Consolidated, Inc. Even though milling practice at Catavi was excellent, the large daily tonnage of ore treated and the several million tons of impounded tailings determined that the first work should be done there. The "slime tailing" from this plant represented one half of the total tailing and, since it contained the major portion of the tin loss, appeared to be a promising product for investigation. A sizing analysis and distribution of tin content through the various sizes of this product are given in table I.

Of the material shown in table I, the sizes coarser than 325 mesh have consistently low tin contents. In lieu of a complete mineralogical study on these products, but, as determined by spot microscopic examinations, we considered that the tin in this range was composed of locked grains.

The four grades from —325 mesh to +9 microns contained 47 pct of the tin content of this product. It was therefore apparent that if gravity concentration could be extended into the fine-size range, a substantial improvement in total tin recovery might be realized.

Pilot Plant: A pilot plant of 5-ton per day capacity was constructed for test work on a continuous cut from the slime tailing launder. The flowsheet is given in fig. 1.

The Akins classifier made a separation at about 65 mesh. This coarse sand contained very little free tin but was tabled in a batch operation for checking purposes. The constriction-plate classifier was a laboratory adaptation of one cell of a Fahrenwald classifier and was used to make a separation at 200 to 270 mesh. The concentrating table in the continuous tests was used primarily to provide a check on the control of the classifier.

The thickener was operated as a hydroseparator making a size separation at 9 microns. A portion of the underflow could be returned to the thickener to obtain the required density of feed in the surge tank. The experimental Sullivan deck used in these tests consisted of a hand-tilted deck, 18 in. wide by 6 ft long, with a surface of rubberized riffle cloth (figs. 2 and 3). In operation, the feed was allowed to flow over the deck for a predetermined length of time, usually 5 min. Following this, the feed was shut off, the deck tilted to a steep angle and the rougher concentrate washed into a catch basin. This rougher concentrate was cleaned and recleaned on the Sullivan deck in subsequent batch operations by using only the surge tank and the deck of the circuit. The recleaned concentrate was brought up to final grade by treatment on the laboratory concentrating table, which was a diagonal-deck table with all dimensions one half of those of a standard Deister slime table. Final grade, as used here, means a pyrite-cassiterite gravity concentrate of from 20 to 25 pct Sn. (Flotation of the pyrite would produce a shipping concentrate of better than 51 pct Sn.)

A typical analysis of the feed to the deck is presented in table II.

When treating a feed approximately that as given in table II, the following rates and conditions were used for Sullivan deck operation: pulp flow, U. S. gal per min per ft width, 1.1; pct solids in pulp, 15.5; dry short tons per 24 hr, 1.36; dry short tons per 24

Table I. Slime Tailing—Catavi Mill

Size	Pct Wt	Pct Sn	Pct Dist., Sn
+ 48 mesh	1.9	0.25	0.71
65	1.5	0.20	0.45
100	4.2	0.16	1.00
150	7.3	0.18	1.95
200	10.4	0.21	3.28
325	11.6	0.31	5.36
+ 26 micron[a]	2.7	2.46	10.12
18	7.9	1.05	12.44
13	7.0	1.18	12.39
9	7.2	1.13	12.18
— 9	38.3	0.70	40.12
	100.0	0.67	100.0

[a] All subsieve sizing was made by sedimentation in beakers according to the settling rate of cassiterite (sp gr 7.0) as calculated from Stokes' law.

Table II. Size-Assay Analysis of Sullivan Deck Feed

Size	Pct Wt	Pct Sn	Pct Dist., Sn
+ 270 mesh	14.4	0.15	3.4
+ 400 mesh	24.2	0.20	7.6
26 micron	3.9	2.30	13.9
18 micron	14.7	0.90	20.7
13 micron	20.3	0.92	29.2
9 micron	9.8	0.77	11.8
— 9 micron	12.7	0.67	13.4
	100.0	0.64	100.0

Table III. Size-Assay Analysis of a 51 Pct Sn Concentrate from Sullivan Deck Concentration Followed by Pyrite Flotation

Size	Pct Wt	Pct Sn	Pct Dist., Sn
+ 270 mesh	1.0	5.9	0.1
400 mesh	0.9	31.2	0.6
26 micron	10.8	58.9	12.6
18 micron	38.4	57.4	43.8
13 micron	39.4	47.6	37.2
9 micron	8.8	31.0	5.4
— 9 micron	0.7	19.6	0.3
	100.0	51.0	100.0

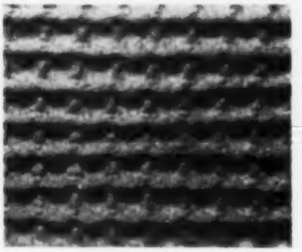

Fig. 2—Rubberized riffle fabric.

Fig. 3—Experimental Sullivan deck.

hr per ft width, 0.91; tilting cycle, min., 5; and slope, in. per ft, 1.85. Pilot plant tests indicated that 27.2 pct of the tin in the Catavi slime tailing could be recovered. This corresponds to an overall increase in mill recovery of 3 pct.

Table III indicates the size range of cassiterite recovered.

Full-sized Plant: A Sullivan deck plant of several hundred tons per day capacity commenced operations at Catavi in 1944. It was designed and constructed on the basis of the results of the above-described pilot plant. The operation proved profitable from the beginning and the construction cost of the plant was repaid in less than one year. Tin was recovered at a cost of 8c to 10c per lb up to at least 1947. Reports indicate that a profitable operation has continued.

The actual recoveries were lower than test work indicated, mainly because less recoverable tin was present in the tailing than in 1943. Recovery from the finest sizes (—18+9 microns) was equal to test results, but recovery from the coarse sizes was less. Plant practice in the coarser range had improved in the meantime.

Test Work, Colquiri Mill

The Colquiri mill, operated by Mauricio Hochschild, had a capacity of 600 to 800 tons per day. Mill records showed that from 30 to 40 pct of the total tailing losses occurred in the slime tailing. Size analysis, assays, and distribution of tin content are shown in table IV.

It will be noted that only 10.5 pct of this product was in the —13 micron size range. This is due to the fact that the true slime from the mill (that is, finer than may be recovered by known methods of gravity concentration) was removed without retreatment as the overflow of two thickeners.

The quantity of sulphur present indicated a much higher content of sulphides than is desirable in the feed to the Sullivan deck. The excess iron beyond that which is accounted for by the sulphur was in the form of siderite, a troublesome problem at this particular plant. To eliminate the sulphides, the sample was first treated by flotation. The flotation non-float was then classified into three sizes which were approximately +100 mesh, —100 +270 mesh and —270 mesh. Size analyses of the coarse and intermediate sizes appear in table V.

The intermediate size was treated on an 18 in. by 6 ft laboratory Sullivan deck under the following conditions: slope 2.3 in. per ft, rate of flow 12 liters per min and, pulp density 16 to 20 pct solids. The pulp was fed continuously for 5 min and then a 30-sec wash of clear water was used before the table was tilted to wash the concentrate into the catch basin. This Sullivan deck concentrate was further treated on a standard Deister slime table to produce a final concentrate.

The finest size was treated on the Sullivan deck also. The procedure was slightly different, however, in that two stages of Sullivan deck concentration were used and no period of clear water washing was employed. Operating conditions were as follows: slope 1.1 in. per ft; rate of flow, 8 liters per min, and pulp density 15 to 18 pct solids. The cleaner concentrate was taken to final grade on the same Deister table used for the intermediate size. In this concentrate, 95.6 pct of the tin was in the size range

Table IV. Slime Tailing Colquiri Mill

Size	Pct Wt	Pct Fe	Pct S	Pct Sn	Pct Dist., Sn
+ 48 mesh	2.14	27.2	21.4	0.75	1.31
65	4.51	27.0	22.0	0.80	2.96
100	6.96	24.0	19.1	0.50	2.85
150	11.67	21.9	16.1	0.85	8.13
200	18.69	24.2	15.9	0.75	11.48
270	10.50	24.8	15.4	0.95	8.24
400	8.77	25.0	15.2	1.15	8.26
26 micron	7.40	30.0	14.5	3.20	19.40
18	9.93	25.5	13.3	2.20	17.90
13	8.70	19.2	8.7	1.45	10.44
9	2.38	17.4	7.5	1.20	2.34
— 9	8.17	14.3	5.4	1.00	6.69
Composite	100.00	24.1	14.4	1.22	100.00

Table V. Laboratory Classification of Slime Tailing, Colquiri Mill

	Coarse Size		Intermediate Size	
Size	Pct Wt	Pct Sn	Pct Wt	Pct Sn
+ 28 mesh	3.38	0.80		
35	5.31	0.85		
48	9.26	0.75		
65	18.44	0.70		
100	26.17	0.60	4.49	0.30
150	23.72	0.70	18.40	0.40
200	9.06	2.35	33.03	0.45
270	1.49	13.10	15.54	1.20
400			15.48	2.65
—400	3.23	5.75	13.06	6.20
Composite	100.01	1.19	100.00	1.65

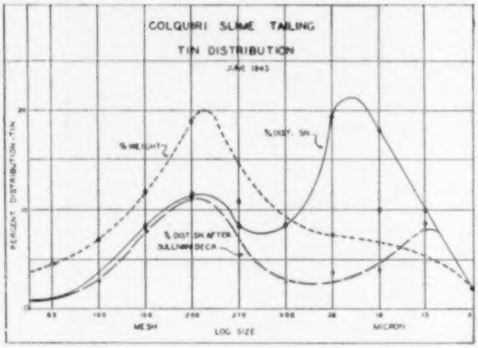

Fig. 4—Colquiri slime tailing tin distribution.

finer than 400 mesh and coarser than 13 microns. Fig. 4 shows the tin distribution in the slime tailing of the Colquiri mill and also what the calculated tin distribution would be after treatment of this product on Sullivan decks. The latter curve was obtained by subtracting the weighted percentage of tin in the pilot plant concentrates from the figures used for the original curve.

The results of the test work on the Colquiri slime tailing are presented in table VI. The total recoveries are shown to be 34.2 pct as a high-grade concentrate and 7.7 pct as a low-grade concentrate. By the use of classification in conjunction with the Sullivan deck it was proved therefore that tin at least as fine as 13 microns could be recovered and also that a high-grade concentrate could be made with a very satisfactory rejection of the troublesome mineral, siderite. These results gave promise of an additional total mill recovery of at least 6 pct.

Following the recommendations made as a result of this test work, the company installed a full scale Sullivan deck plant. The improvement in recovery is reported to have been as satisfactory as the pilot plant results predicted.

Table VI. Test Results Colquiri Slime Tailing

	Pct Wt	Pct Sn	Pct. Dist., Sn	
Feed to pilot plant	100.0	1.22	100.0	
Pyrite float	32.6	0.72		19.4
Classification				
Coarse size	11.4	1.14		10.7
Intermediate size	26.2	1.50		32.2
Fine size	29.8	1.54		37.7
				100.0
Concentration				
Coarse size				
Table concentrate	0.16	26.3		3.2
Intermediate size				
Deck concentrate	4.0	7.4	24.2	
Final concentrate	0.32	62.9		16.4
Middling	0.10	32.8		2.6
Fine size				
Deck concentrate	3.0	10.1	24.8	
Final concentrate	0.35	60.9		17.8
Middling	0.08	28.6		1.9
Total concentrates	0.67	61.9		34.2
Total middlings	0.34	28.7		7.7
Total tailings	98.99	0.72 (calc.)		58.1

Table VII. Sizing Analysis

Mesh or Microns	Pct Wt	Pct Sn	Pct Dist., Sn
270 mesh	8.42	10.96	2.44
37 microns	16.72	30.14	13.10
18 microns	35.24	38.48	35.95
10 microns	34.77	49.70	45.83
—10 microns	5.35	18.93	2.68
	100.00	37.7	100.00

Additional Plant Results

Installations were made in a total of 6 tin mills during 1944 to 1946. Test work in 1943 had also shown very good results for two tungsten ores, one containing wolframite, the other scheelite. These latter two plants did not go into production because of the collapse of the tungsten market late in 1943.

Most plants gave recoveries close to those estimated from the test work. Two plants gave better results than predicted. One plant, where good records were kept, treated an extremely difficult ore. The tin occurred in aggregates of very fine cassiterite of near colloidal grain size. The Sullivan Deck section in this plant accounted for 40 pct of the total production. A sizing analysis of the concentrate is given in table VII.

This appears to be the only record of a gravity concentration mill in which nearly half (44 pct) of the total concentrate is finer than 37 microns. The tin ore from this mine was largely in the form of a mud and the most careful grinding could not prevent the production of slimes which were naturally present in the ore body.

Operating Suggestions

The importance of dispersing the pulp and of desliming prior to fine-size classification and Sullivan deck concentration has been proved in practice. Sodium silicate (up to 1 lb per ton) has been used as a pulp dispersant. Other dispersants may be equally effective and economical.

In the course of the pilot plant test work, it was noticed that the normal pulp waves on the Sullivan deck caused sufficient agitation to lift many of the fine particles that had already settled to the surface of the deck. In an effort to reduce the size of these waves, a surface tension effect, small quantities (0.3 lb per ton) of pine oil were added ahead of the deck. The waves were reduced in magnitude, the grade of the tailing decreased and the grade of the concentrate increased. Such a use of reagents in gravity concentration may be worth investigating further.

During the progress of the pilot plant test work, the Sullivan deck concentrate was graded up to shipping quality by the use of shaking tables. This is admittedly not the best method for minerals in the size range finer than about 18 microns. Other tests have shown that Vanners are more efficient for this final cleaning operation on the very fine sizes.

Conclusions

Pilot plant tests on Bolivian tin mill tailings proved that gravity concentration could be conducted economically on mineral particles much finer than were treated formerly. The novel features of the method are the combination of desliming, fine-size classification, and the treatment of the classified products on the Sullivan deck. The method has been successfully applied to the treatment of the "slime tailing" from many mills using conventional jig and table circuits.

Fig. 1—Index map showing location of principal quarries in the Crab Orchard District.

Building Stone of the Crab Orchard District, Tennessee

by Benjamin Gildersleeve

Uniquely colored, thin-bedded quartzite is quarried between Crossville and Crab Orchard in Cumberland County, Tenn. It is produced in all sizes up to the limits of transportation from beds usually ranging in thickness from less than ½ in. to 6 in. The stone is very resistant to wear and weathering and is marketed throughout the country for many different purposes in exterior and interior construction. The annual production exceeds 36,000 tons, valued at nearly $1,000,000.

THE building stone of the Crab Orchard District is a fine-grained, thin-bedded sandstone which is so strongly cemented by silica that it may be classed as quartzite. As used in this paper the term building stone includes dimension stone, rubble, ashlar, flagstone, and rough broken stone.

The Crab Orchard District is in the central portion of Cumberland County, Tenn. It is named from the town of Crab Orchard near which the stone was quarried first for industrial use. The heart of the district is an area of some 1200 acres from 1 to 3 miles east of Crossville which is 70 miles west of Knoxville and 125 miles east of Nashville (fig. 1). At the present time, there are about 15 quarries worked by companies and individuals.

Geology: The Crab Orchard District is on the Cumberland Plateau, or Cumberland Mountain as it is called frequently. Most of the area is characterized by a comparatively even surface from 1800 to 2000 ft in elevation and is drained by streams flowing into the Tennessee River. Included in the district are two quarries located 7 miles west of Crossville and this area is drained by tributaries of the Cumberland River. Most of the quarries are located near the 1800-ft contour which is just below the general upland surface.

The surface rock over most of the district is the Rockcastle sandstone which has a thickness of about 260 ft.[1] It is the topmost of the six formations of

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Fig. 2—Slab of stone 15 ft long, 10½ ft wide, 3½ in. thick. Scale at right is 6 ft.

alternating sandstones and shales comprising the Lee group of Pennsylvanian age.[2] The principal quarries are in the Rockcastle, however, the westernmost operations included in the district have been opened in the Bonair sandstone the top of which is between 140 and 200 ft stratigraphically below the Rockcastle.[1] Generally through the region, the Rockcastle is notably cross-bedded, however, this condition is less pronounced in the main quarries. In general, the strata are gently warped into broad synclines and anticlines which trend northeastward across the district. Locally there are more strongly developed folds and well-defined faults.

Character and Uses: The stone is predominantly a multicolored, fine-grained, thin-bedded, quartzitic sandstone. It occurs in beds of remarkably uniform thickness that usually vary from less than ½ in. to 6 in., with several ledges from 6 to 22 in. The quartzite is easily separated along its bedding planes and may be quarried in very large pieces of uniform thickness with smooth surfaces up to handling and transportation limits (fig. 2). The maximum size used is about 16 ft long, 11 ft wide, and 3 in. thick. To date the largest single sheet quarried in one piece was 111 ft long, 8½ ft wide, and 3 in. thick. Of necessity this sheet, weighing approximately 19 tons, was reduced to pieces which could be handled and shipped. Quarried stone can be broken readily without splitting and with equal ease in all planes perpendicular to the bedding. The colors are monotones of tan, buff, gray, blue gray with various blending shades of yellow, brown, mauve, red, and pink forming stripes, swirls, and an infinite variety of designs, some of which resemble fern leaves and geometrical figures.

The following generalizations are based on laboratory data furnished by the producers: (1) Composition, from 93.54 to 94.87 pct silica; from 3.60 to 4.48 pct alumina and iron; the remainder made up principally of titanium and small amounts of calcium, magnesium, and alkalies. (2) Weight per cu ft, 160.7 to 162.7 lb. (3) Crushing strength, 18,760 to 28,050 psi. (4) Absorption, 0.92 to 0.98 pct.

As a building stone this quartzite is accorded high rank because of its pleasing colors, strength, durability, imperviousness, inertness to acid-laden gases present in the atmosphere of smoky cities, and availability in many sizes, either irregular and rough broken, or shaped to specified dimensions. It is used as dimension stone, rubble, ashlar, flagstone, and rough broken stone for many purposes. In exterior work it is used for roofing; as even-course stone or as broken ashlar for entire walls; for trim on buildings made chiefly of brick, limestone or other materials; for copings, lintels, window sills, treads, terrace floors, paving, garden furniture, retaining walls, memorials, etc. For interior use it is employed as floor tile, wainscoting, trim, decorative panels, fireplace facing, and hearths.

Stone from the Crab Orchard District has been used throughout the country in the erection of structures combining attractiveness and permanence. Many examples could be cited of its architectural use in residences, churches, hospitals, post offices, court houses, offices, and commercial buildings.

Quarry Methods: The overburden, consisting of soil and partially disintegrated sandstone, varies from a few inches up to a maximum of about 12 ft, and averages from 4 to 7 ft. It is stripped well ahead of quarrying and is removed by pans, scrapers, and bulldozers. In places, it is necessary to plow, or scarify, the weathered sandstone immediately overlying the sound rock before it is removed.

The quarries are developed laterally by a series of benches and the average overall face is from 7 to 9 ft. The largest quarry floor covers approximately 15 acres and the smallest is less than 50 ft square (fig. 3). Between these extremes the production is mainly from quarries averaging 5 to 6 acres in extent.

Fig. 3—General view in a large quarry.

Although cross-bedding is present in varying degrees of intensity in all the quarries, in general it does not affect quarrying operations adversely. Throughout the district the thinner beds predominate and vary in thickness from less than ½ in. to 6 in., the greater proportion being from 2 to 5 in. Usually they are most prominent in the upper portions of the quarry face, but are not restricted to this position. The next most common thicknesses are from 5 to 10 in., and a few ledges are found up to as much as 22 in. in thickness.

Joints are nearly perpendicular to the bedding, usually trend SE-NW, and are spaced up to 50 ft apart. Many of them are curved and vary as much as 30° (N 50 to 80° W) along their strike. Frequently the joints are off-set and, as seen in the quarry face, may be likened to the vertical divisions in a brick wall. The presence of clay parting seams along the bedding and the partially weathered character of the stone along many of the joints greatly facilitate quarrying.

Quarry methods now employed are quite simple and most of the work is done by hand. Wedges are

driven at short intervals along open seams parallel with the bedding. The stone is then loosened and lifted from the quarry by using crowbars and mattocks. To assist in making straight cross breaks in the thinner beds, a gad is struck successive blows with a sledge hammer along the lines of desired parting. In beds 6 in. or more thick, holes are drilled with jackhammers to a depth of 3 or 4 in. at intervals of about 10 in. along the desired line of break. Plug-and-feather wedges are placed in the holes and sledged in succession beginning at one end of the line (fig. 4). Although the steel bits are dulled rather quickly by the very abrasive stone, their use has been found less expensive than those tipped with tungsten carbide. One operator reports that the cost of drilling with tungsten carbide bits is approximately one and one half times that of steel bits.

Quarry waste is handled with Brooks load luggers, and other trucks are used to transport the quarried rock to stockpiles and to shipping points. The larger pieces that are too heavy to be loaded by hand labor are moved by trucks equipped with cranes. Hand trucks are also used to handle material in the quarries.

Fig. 4—Plug-and-feather wedges are used in quarrying the thicker beds.

The quarries have almost automatic drainage because they are shallow and located near the general upland surface. Little pumping is necessary except to remove surface water in times of heavy rains.

Fabrication: The most revolutionary development in the district was the introduction in 1947 of guillotine machines for cutting the stone. These machines are operated by a hydraulic pressure system and have capacities up to 12x48 in. between the cutting blades (fig. 5). At the present time, there are four guillotines of this type in the district. In addition, one producer has built a similar hydraulic machine with two sets of 26 teeth each instead of opposing blades, and having a cutting surface of 60 in. Stone is moved to and from the machines over roller conveyors.

Although the guillotines have made possible increased production and profits, hand cutting is still a major operation in the district. Hammers, points, chisels, pitching tools, and tracers are the hand tools most commonly used. The stone is supported on strong work benches at a height convenient for working. As previously mentioned, the stone breaks easily in all planes perpendicular to the bedding, consequently, pieces can be trimmed either in rectangular or in circular shapes. The pieces are marked and broken in a manner similar to that used in cutting plate glass. After a tracer tool has been sledged along the desired trim line, a sharp blow will cause the stone to break without fracturing. The thicker ledges, when cut in this fashion, may have somewhat irregular faces which are roughened down to comparatively uniform surfaces with pitching tools and hammers. These hand tools are also used to rough down blocks of rubble stone cut with guillotines.

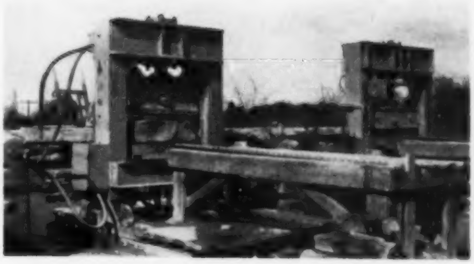

Fig. 5—Guillotine machines for cutting the stone.

The stone does not take a very high polish and it is so abrasive that machine work is both difficult and expensive. Consequently, only a limited amount of sawing, rubbing, and sand blasting is done. Both diamond and carborundum saws are used.

Production and Marketing: It is estimated that approximately 450 men are employed in the industry, and that the annual production is over 36,000 tons, valued at nearly $1,000,000. Over 90 pct of the output in the district is produced by three operators, namely: Crab Orchard Stone Co., Inc., Tennessee Stone Co., and Turner Brothers Stone Co., Inc.

Markets for the building stone of the Crab Orchard District are country-wide. It is sold under the commercial names of: Crab Orchard Stone, Tennessee Quartzite, Tennessee Variegated Stone, Cumberland Mountain Stone, Chromastone, and Tennessee Ledge Rock. The stone is sold according to thickness and general quality. Prices for rubble and other rough broken stone range from $5.00 to $35.00 a ton. Flags, trim, sills, coping, and other pieces with straight broken edges, or cut to specifications, bring special prices according to thickness and vary from $0.25 to $3.50 a sq ft.

Acknowledgments

The cordial interest and cooperation of the quarry operators and property owners is greatly appreciated. Thanks are expressly given to E. Rohde and H. A. Schubert, Tennessee Stone Co., for assistance in making a reconnaissance survey of the principal quarries and for furnishing data on quarry methods and marketing; to R. N. Pelot, Crab Orchard Stone Co., Inc., for information on quarrying, fabrication, and other aspects of the industry; to the Turner Brothers Stone Co., Inc., for data on their quarry and the district; and to residents in the district for information about old quarries and the growth of the industry.

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Fluoride in Ground Water of Alabama

by Philip E. LaMoreaux

Fluoride, generally less than 0.5 ppm, is present in ground water from rocks of Paleozoic age and older, in northern and eastern Alabama. Some of the water-bearing formations in the Coastal Plain area of the State yield water with as much as 6.8 ppm fluoride.

IN June 1940, the U. S. Geological Survey, in cooperation with the Geological Survey of Alabama, began a study of the ground-water resources of the part of Alabama where water is obtained from Cretaceous rocks. The purpose of the study was to determine the quality, quantity, occurrence, and availability of ground water in that area.

These studies have been expanded to include ground-water investigations in the area of Tertiary rocks, or southern quarter of the State, and certain areas in northern Alabama.

The first report issued on these studies was by C. W. Carlston,[1] of the Alabama Geological Survey. In the present paper all references to ground-water data for the Cretaceous area are taken from this earlier publication.

In 1945, the Dentistry Division of the Alabama Department of Public Health became interested in the correlation of tooth decay and mottled enamel with the chemical quality of ground water used for public supplies in the State. Through a cooperative arrangement between the State Department of Public Health and the Ground Water Division (now Branch) of the U. S. Geological Survey, a report by the author[2] was published in 1948. These two reports give accurate information on the occurrence of fluoride in the Coastal Plain of Alabama.

At present, only scattered information is available on fluoride in ground water of the crystalline-rock or Piedmont area and for the Paleozoic area of Alabama, but it is hoped that in the future more complete information on the presence of fluoride in ground water in these areas can be collected.

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Outline of Geology and Ground Water: As described by Adams,[3] the State of Alabama includes parts of two major geologic divisions, the Appalachian region and the Coastal Plain. The boundary between these divisions is irregular and is known as the Fall Line of the Atlantic and Gulf Coast States. The Fall Line enters Alabama near Phoenix City, extends westward to Wetumpka, Clanton, and Tuscaloosa, and then swings northwestward to the northwest corner of the State.

The Appalachian region in Alabama includes three major provinces, the Piedmont province, the Appalachian Ridge and Valley province, and the Appalachian Plateau province (fig. 1).

The rock formations in the Piedmont province in east-central Alabama are mainly of pre-Cambrian age, chiefly crystalline schists and gneisses injected by younger igneous rocks (fig. 1, I). They are faulted and folded and have a complicated structure. These rocks are the oldest and among the most complex rocks in the State. Generally, only small yields of ground water are obtained from rocks in this area. Even though ground water is of great importance for the development of domestic and farm supplies in rural areas and a few small industrial and municipal wells, yields in the area from individual wells generally range from 5 to 25 gpm and rarely exceed 50 gpm.

The geologic formations of the Appalachian Ridge and Valley province and the Appalachian Plateau province (see fig. 1, II, and III) are separated on the basis of their structure. These rocks are of Paleozoic age, ranging from Cambrian to Carboniferous, and comprise a succession of formations consisting chiefly of shale, sandstone, limestone, and dolomite, aggregating many thousands of feet in

thickness. The limestones and dolomites and some of the sandstones in this area yield large quantities of ground water for industrial and municipal supplies, and smaller ground-water installations supply the entire rural area.

The rocks of the Alabama Coastal Plain area in the southern and western parts of the State are divided into two major age groups, the Cretaceous and Tertiary (fig. 1, IV *A* and *B*). These Cretaceous and Tertiary formations dip south toward the Gulf of Mexico in eastern and central Alabama and southwest toward the Mississippi Embayment in western Alabama at low angles, from 20 to 50 ft per mile. These formations consist primarily of unconsolidated silt, clay, sand, gravel, and limestone, and exceed 5000 ft in total thickness in southwest Alabama. Ground water developed from wells and springs is of great importance to the Coastal Plain area of the State. Nearly every city and water-consuming industry depends on ground water. In the rural areas nearly every farm has its own well or spring.

Summary of Results of Dental Investigations: Knowledge of the influence of fluoride on tooth enamel and tooth decay is by no means new, for Crichton-Browne[4] in England in 1892 speculated on the correlation of dental caries or tooth decay with fluorine in the diet. Much additional work, especially during the last 20 years in the United States, has been carried forward on the studies of the relation of the amount of tooth decay and mottling of tooth enamel to the amount of fluoride in drinking water. A general summary of this work in the United States shows fluoride to have two effects on the development of teeth, (1) mottled enamel (dental fluorosis) from too much fluoride in drinking water, and (2) reduction of tooth decay (dental caries) from the presence of smaller quantities of fluoride.

H. Trendley Dean[5], dental surgeon of the U. S. Public Health Service, points out that the "harmful factor" or mottled enamel is on the permanent teeth and results from drinking water that contains toxic quantities* of fluorine during the time of development of the permanent teeth. In other words, only children under 8 yrs of age are susceptible to this dental defect. Fortunately, there are beneficial effects of water containing small amounts of fluoride. Dean[5] has summarized this aspect as follows:

> An inspection of the range of dental caries experience associated with the use of domestic water of different fluoride concentration discloses an inverse relation in general between the amount of dental caries and the fluoride concentration of the common water supply. Relatively low dental caries experience rates are found associated with the use of domestic waters whose fluoride (F) concentrations have a range of 1 or more parts per million. Intermediately, e.g., at concentrations of 0.9 to 0.5 part per million, the influence is less marked than at the higher concentrations; nevertheless, the dental caries experience rates are distinctly lower than those associated with the use of relatively fluoride-free waters.

Fluoride in Ground Water of Alabama: Few chemical analyses have been made on samples of water collected from the crystalline-rock area of the State. The following information, therefore, necessarily is highly generalized. For the most part, water from wells in the crystalline-rock area is fairly low in dissolved solids and no samples of water from this area showed toxic quantities of fluoride. In general, the fluoride content of samples of water from wells in the crystalline rocks ranged from a trace to 0.5 ppm. Some samples contained no fluoride.

Fig. 1—Outline of Alabama showing geologic provinces.

Though the information for the Paleozoic area of northern Alabama is somewhat better than that for the Piedmont area, the number of chemical analyses is not sufficient to give an accurate report on fluoride in ground water in the area. In general, water from sandstone and limestone in the Paleozoic rocks of northern Alabama contains from a trace to 0.2 ppm of fluoride. One exception to this was a well drilled in the Warsaw limestone near Huntsville, Madison County, Ala. This well yielded water containing 3.6 ppm of fluoride from a solution cavity in limestone.

Many of the analyses of water from the Coastal Plain deposits of Alabama show the presence of fluoride. It is interesting to note, from a bar graph prepared by the Dentistry Division of the State Department of Health during a preliminary dental survey of the State, that the counties with the largest percentage of children having nearly perfect teeth are counties in which analyses of well water show appreciable amounts of fluoride.

The deposits of the Coastal Plain have been divided into two groups, the Cretaceous and Tertiary, according to geologic age. The principal water-

* More than 1 ppm according to the 1942 paper; over 1.5 ppm according to present standards of the Public Health Service.

bearing beds of the Upper Cretaceous deposits in Alabama include the sands of the Tuscaloosa group and the Eutaw, Blufftown, and Ripley formations and the Cusseta and Providence sands. Of these, the glauconitic sand beds of the Eutaw, Blufftown, and Ripley formations yield water containing up to 6.8 ppm of fluoride. The heaviest concentrations of fluoride (6.8 ppm) in Alabama were found in water from wells penetrating the Eutaw formation at Letohatchie in Lowndes County.

Nearly every Tertiary formation has a sandy or limestone facies that is a potential source of ground water. Many municipal and industrial wells recorded in the ground-water study of the Tertiary area were developed in the sands of the Nanafalia formation, Tuscahoma and Gosport sands, and Lisbon formation, from solution channels in the Ocala limestone, and from sands in the Miocene beds and the Citronelle formation.

Of the representative samples of water from wells tapping these formations only two had a fluoride content of 1 ppm or more. One well yields water from the Nanafalia formation at Thomasville in Clarke County, the other well yields water from the Lisbon formation at Gilbertown, Choctaw County. In general, the fluoride content of the samples of water from the Tertiary formations was 0.5 ppm or less.

Source of Fluoride in Ground Water: Relatively little information is available on the amount and distribution of fluoride in rocks, particularly in sedimentary rocks, because until recent years accurate methods of determining small amounts of fluoride in the analysis of rocks have not been available. As the amount of fluoride in ground water differs from place to place, it appears that a direct relation exists between the composition of sedimentary material and the amount of fluoride present in water from that sediment. Several theories have been advanced as to the source of fluoride. In some regions fluoride may be traced directly to magmatic sources, to vapors in the atmosphere from a volcanic vent, or to volcanic ash and tuffaceous materials in sediments.[6] Another possibility may be that fluoride present in sea water during the original period of deposition of a marine bed has not been flushed out completely. Fluoride may also be furnished by weathering or solution of some of the more common fluorine-bearing minerals, such as apatite, tourmaline, topaz, vesuvianite, lepidolite, or glauconite, in the rocks through which ground water percolates. If these fluorine-bearing minerals are the source, they would have to be affected by some erosional process that would release the fluoride in soluble form.

Gwynne[7] suggests that the breaking down by weathering processes of the more insoluble fluorine-bearing minerals might be accomplished by the action of sulphuric acid formed by the decomposition of pyrite contained in a sedimentary rock. Van Burkalow[8] theorizes that fluoride in soluble form should be expected where two conditions prevail: (1) an abundance of fluorine-bearing minerals, and (2) an abundance of pyrite in association with concentrated organic material that would facilitate the decomposition of the fluorine-bearing minerals. To check these theories, lithologic data were compiled on the water-bearing formations of the Coastal Plain of Alabama. The presence of phosphates, bentonite, pyrite, lignite, glauconite, and other fluoride-bearing minerals was checked against the occurrence of fluoride in the water. It was found that high fluoride content in ground water from formations in the Alabama Coastal Plain area is associated with the presence oi abundant phosphatic material, pyrite, lignite, and glauconite. In addition to this information, it was discovered that, in general, the deeper wells penetrating water-bearing sands containing these minerals and yielding water high in fluoride had greater concentrations of fluoride than the water from shallower wells penetrating the same sands up the dip. This indicates the possibility that the amount of fluoride in the water may be related not only to the presence of certain minerals in deposits but also to the depth to the formation and the distance to the outcrop, and therefore, to the extent of ground-water circulation and the length of time the water has been present in the deposits. It is also possible that greater pressure and temperature at greater depths promote the reaction.

Summary: The water from the glauconitic sands in the Eutaw, Blufftown, and Ripley formations of the Coastal Plain deposits contains larger amounts of fluoride than does that of any other formation in the State, as far as known. Samples of water from wells in the Eutaw and Ripley formations used for public supplies in the central Coastal Plain area, including Greene, Dallas, Montgomery, Marengo, Wilcox, Lowndes, Barbour, and Butler counties, contain from 1 to 6.8 ppm of fluoride. The fluoride content of samples of water from wells in the Tertiary area or southern quarter of the State ranged from a trace to 1.2 ppm.

To date, only a limited number of samples have been collected in the Piedmont crystalline-rock area of Alabama and Paleozoic area of northern Alabama. The fluoride content of 10 of these samples, with one exception, was zero. One sample contained 3.6 ppm of fluoride. It is possible that, with more detailed studies, higher concentrations of fluoride will be found, although it is believed that in general the fluoride in ground water will not exceed 1 ppm in this area.

In areas where high fluoride concentrations occur, it is usually possible to obtain water free from fluoride by drilling to overlying or underlying formations. Therefore, after more complete information is available on the effects of fluoride, it may be possible to combine fluoride-free water with fluoride-bearing water to obtain the optimum amount of fluoride necessary for health.

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An Oxidation Method

For Investigating the Petrographic Composition of Some Coals

by Reynold Q. Shotts

Data are presented which show that fractions of varying densities from the same coals are oxidized at different rates by nitric acid. From oxidation data, the approximate quantity of "bright" and "dull" components may be calculated. Definite relationships between oxidation rate and rank are shown for density fractions from at least two bituminous coals.

IN 1945, the Alabama State Mine Experiment Station initiated a program on the determination of fusain in certain coals of the state.[1] Because of the lack of equipment and personnel necessary for microscopic examination, the chemical method[2] was used exclusively. During studies of the distribution of fusain in fractions of various sizes and densities on a medium volatile coal, the author noted a higher rate of oxidation of the nonfusain part of the coal in the lower density fractions and the difference in rate became more marked the shorter the oxidation period used. Since durain and other "dull" components of coal have been reported[3, 4, 5] to have higher densities than vitrain and the bright components, it appeared probable that the observed differences in rates of oxidation in the different density fractions were due to variations in petrographic composition. Such effects have been noticed by other workers.[5, 6]

In order to obtain further evidence on this point, several Alabama coals of different rank have been separated into three or more fractions on the basis of density and their rates of oxidation determined, using the procedure specified for the determination of fusain, except that measurements were made at short time intervals as well as for the longer periods specified in the regular procedure. Significant differences in the rates of oxidation of the nonfusain part of the various fractions have been observed, and it is believed that studies of this type may make possible the identification of individual petrographic components or lead to methods for their semiquantitative estimation.

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Properties of the Coals: Analyses and some properties of the whole coals studied are given in table I. The range in rank of the coals is not the widest possible within the state, but samples of the low volatile coals that occur in thin beds in the northeastern part of the state, were unavailable.

The Clements bed is not, at present, considered workable. The coal is of medium volatile rank, quite friable, and very strongly swelling. Analyses of different size fractions show that the larger sizes are of higher rank than the smaller ones. Material passing the No. 50 sieve (all sieve sizes refer to the U. S. Standard Series) is close to high volatile A in rank, except for the size passing a No. 200 sieve, in which fusain is partially concentrated. Because of the variation in rank of the sizes of Clements coal, oxidation studies were made of two widely different size ranges. The + 1-in. material was crushed on rolls to about ⅛ in. and separated into five fractions by float-and-sink treatment in a benzene-carbon tetrachloride mixture. The — No. 4 + No. 8 and the — No. 4 + No. 50 size ranges tested overlap but the latter size was studied last with the expectation that it would include more oxidizable material than the first size. This proved not to be the case. Yields and properties of the specific gravity fractions oxidized are shown in table II.

Milldale bed coal probably represents, as nearly as it is possible to do so, the "average" coal of the state. The material passing a No. 4 sieve was the only size range oxidized. It was divided into four specific gravity fractions. As in every case the heaviest fraction, which was essentially rock, was discarded.

The Black Creek is the most extensive in area of

Table I. Properties of the Whole Coals

Bed	Analyses							Fusain[c]			
		M	A	VM	FC	S	Btu	Content	FSI	Rank	Condition
Clements	[a]	1.1	8.4	25.9	64.6	2.1	14,150	3.3[d]	9+	Med. vol. Bit.	Raw-mine run
	[b]			27.5	72.5		15,840				
Milldale	[a]	1.8	8.9	32.5	56.8	1.2	13,830	7.7	7½	High vol. Bit. A	Raw-mine run
	[b]			35.6	64.4		15,660				
Black Creek[e]	[a]	2.6	3.9	36.4	57.1	1.5	13,910	[f]	1½	High vol. Bit. A	Washed slack[g]
	[b]			38.4	61.6		14,980				
Clarke County Lignite	[a]	12.6	5.8	41.1	40.5	3.7	8,950	1.3	NA[h]	Lignite[i]	Raw
	[b]			49.5	50.5		11,080				

[a] Air dry basis.
[b] Dry, mineral-matter free (Parr) basis.
[c] Moisture and ash-free basis.
[d] Slack passing a 1¼ in. square opening.
[e] Black Creek group. Bed designated Jefferson in late Bureau of Mines reports.
[f] Not determined. Black Creek Bed known to contain considerable fusain.
[g] Passing a 1¼ in. square opening. A light water spray over a No. 30 wedge wire screen, was observed to remove a little material.
[h] Non-agglomerating.
[i] "Bed" moisture unknown. See ref. 6.

the coal beds of the state. In the northwestern part of the Warrior field it is the lowest in rank of any of the coals mined in Alabama. Only the — No. 4 + No. 50 sieve size was subjected to oxidation studies. The material passing a No. 50 sieve was very high in fusain (samples No. 118, 119, table II) and was removed to facilitate the float-and-sink operation.

Thin beds of lignite occur in the upper Cretaceous and Tertiary formations in many places in Alabama, the most extensive occurrences being in the Wilcox Group of Tertiary Age.[6] A small sample was obtained from a 14-in. bed in a new highway cut. Nitric acid oxidations and analyses were not made until after more than a year of storage in the laboratory. No determinations of "bed" moisture could be made but there is no doubt that the sample was lignite.

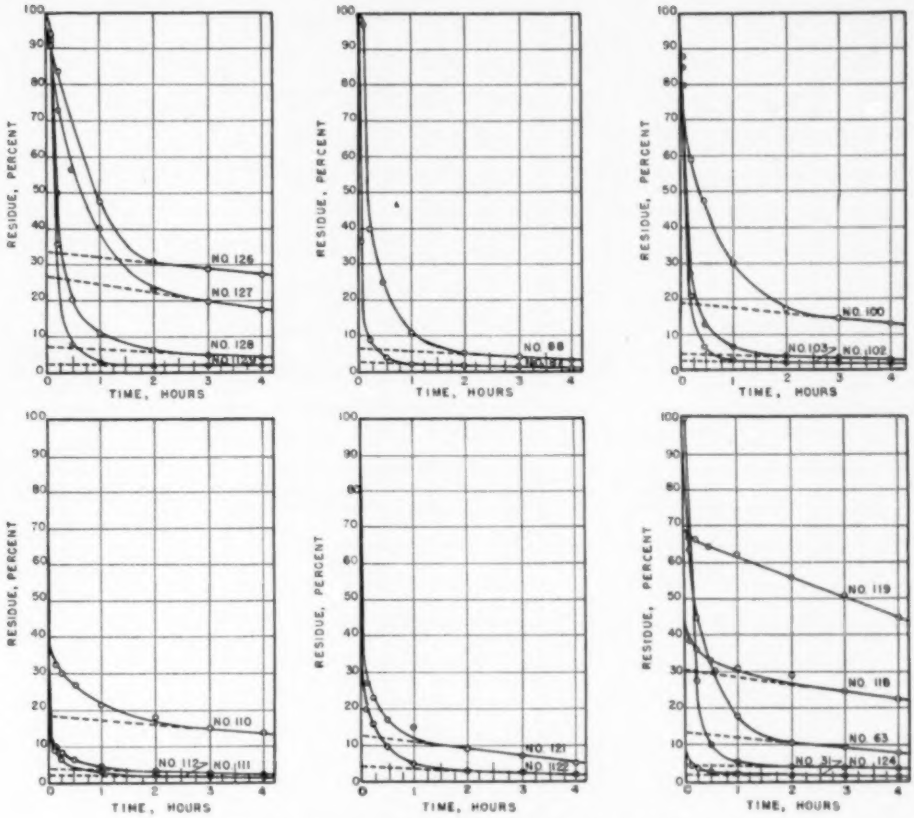
In addition to the lignite, samples of two sizes of raw Clements coal (samples No. 63, 124) and two high fusain, raw coal samples from the Black Creek bed (samples No. 118, 119) were oxidized.

Principles of Procedure: Briefly, the method proposed by Fuchs and associates for the determination of fusain[2] consists of the oxidation of 1-g samples of coal in boiling 8 N nitric acid in a flask fitted with a reflux condenser, for periods of 2, 3, and 4 hr. The unoxidized residue is carefully filtered from the liquid and washed. The residue is transferred to a beaker, treated with 40 ml of normal sodium hydroxide, diluted to 900 ml, and allowed to set overnight. The brown, supernatant liquid is

Table II. Properties of Coal Fractions

Sample No.	Bed and Size	Specific Gravity Limits	Yield, Pct	Proximate Analysis[a]			Fusain[b]	FSI[b]
				FC	VM	Btu		
125	Clements + 1 in.	Sink-1.800	5.5					NA[d]
126	Clements + 1 in.	1.397-1.800	22.6	77.7	22.3	15,120	33.0	1
127	Clements + 1 in.	1.310-1.397	22.1	76.7	23.3	15,750	26.0	4½
128	Clements + 1 in.	1.280-1.310	12.7	73.0	27.0	15,640	6.4	10
129	Clements + 1 in.	Float-1.280	37.1	71.9	28.1	15,520	1.4	10¼
88	Clements No. 4xNo. 8	1.28-1.60	31.7	73.7	26.3	15,670	5.2	9¾
87	Clements No. 4xNo. 8	Float-1.28	65.8	71.9	28.1	15,680	0.8	10
99	Clements No. 4xNo. 50	Sink-1.60	5.7					NA
100	Clements No. 4xNo. 50	1.35-1.60	4.5	75.2	24.8	15,360	18.0	2
102	Clements No. 4xNo. 50	1.27-1.35	21.8	71.7	28.3	15,370	3.1	9¼
104	Clements No. 4xNo. 50	1.26-1.27	27.1	72.2	27.8	15,650		10
103	Clements No. 4xNo. 50	1.25-1.26	38.7	72.3	27.7	15,620	0.9	10¼
101	Clements No. 4xNo. 50	Float-1.25	2.2	71.2	28.8	15,420		10
109	Milldale No. 4x0	Sink-1.60	17.8					NA
110	Milldale No. 4x0	1.32-1.60	18.5	68.1	31.9	15,020	17.5	3¼
111	Milldale No. 4x0	1.283-1.32	38.5	66.6	33.4	15,200	3.1	7
112	Milldale No. 4x0	Float-1.283	25.2	64.2	35.8	15,000	2.0	7½
120	Black Creek No. 4xNo. 50	Sink-1.510	4.8					NA
121	Black Creek No. 4xNo. 50	1.305-1.510	28.1	65.1	34.9	14,400	11.7	1
123	Black Creek No. 4xNo. 50	1.283-1.305	31.1	61.4	38.6	14,520		2
122	Black Creek No. 4xNo. 50	Float-1.283	36.0	55.9	44.1	14,530	3.3	2
63	Clements + 1 in.	Raw		72.9	27.1	15,660	13.3	8½
124	Clements No. 50x0	Raw		71.2	28.8	15,250	4.2	
119	Black Creek — No. 200	Raw		76.7	23.3	14,880	67.0	1[e]
118	Black Creek No. 50xNo. 200	Raw		68.2	31.8	14,640	30.5	NA
31	Lignite	Raw		50.5	49.5	11,080	1.3	NA

[a] Dry, mineral matter-free (Parr) basis.
[b] Dry, ash-free basis.
[c] Free swelling indexes larger than 9 determined by area measurement. (See U.S. Bur. Mines, *R.I.* No. 4238).
[d] NA—non-agglomerating.
[e] Button coherent but could not be handled.



Figs. 1-6—Percentage of residue plotted against time.

Fig. 1. (Upper left)—Clements bed coal, +1-in. size. Fig. 2 (Upper center)—Clements bed coal. —No. 4+No. 8 size. Fig. 3 (Upper right) —Clements bed coal, —No. 4+No. 50 size. Fig. 4 (Lower left)—Milldale bed coal, —No. 4 size. Fig. 5 (Lower center)—Black Creek bed coal, —No. 4+No. 50 size. Fig. 6 (Lower right)—Various sizes of raw bituminous coal and one raw lignite.

removed, the residue filtered, dried, weighed, ignited, and weighed again. The ash-free residue is expressed as a percent of original dry, ash-free coal. The percent residue is plotted against time, using linear coordinates. As a rule, the three points fall along a straight line. The extrapolation of this line to zero time gives the percentage of dry, ash-free fusain present in the original sample. In some cases the 2 hr oxidation may prove insufficient for the solution of all nonfusain material. In such a case, the 3 and 4 hr oxidations are connected with a straight line and extrapolated to zero time.

The method and procedure proposed by Fuchs and associates was followed as closely as was possible under the circumstances. Much trouble was experienced in the case of some coals, by the tendency of the fine material to "crawl" up the sides of the boiling flask. For this reason, most of the determinations were run on — No. 100 material rather than — No. 200 coal as specified by Fuchs. The flattening of the curves after 2 hr of oxidation, figs. 1 to 6, shows little evidence of a "dragging out" of the oxidation of the nonfusain material due to large particle size.

Fuchs and associates explain the shape of oxidation curves like figs. 1 to 6 by assuming them to be compound, or to represent two distinctly different types of reaction. They state that the first part of the curve represents an apparent first-order reaction in which the reaction rate changes with the

Table III. Values of K_c at Various Times

Sample No.	Time, Hr 0.125	0.25	0.50	1.0	2.0
126	1.05	1.11	0.94	1.36	2.28
127	0.87	1.81	1.73	1.51	1.86
128	0.66	3.01	3.86	2.93	2.62
129	0.52	4.27	5.60	4.50	3.10
88	0.42[a]	4.13	3.18	2.81	2.74
87	12.58[a]	10.56	7.36	5.52	3.11
100	2.28	2.80	2.06	1.80	1.38
102	1.07	5.75	4.79	3.51	2.75
103	1.34	6.57	6.19	5.29	3.45
110	13.76	7.40	4.31	2.89	1.86
111	21.74	12.28	7.16	4.39	2.89
112	21.85	13.01	8.00	4.70	2.75
121	14.24	8.26	5.07	3.00	3.39
122	14.48	8.37	5.70	4.17	
63	0.05	4.06	3.11	2.67	
124	3.89	5.68	5.75	4.38	3.43
119	20.0+				
118	17.1	9.87	5.98	3.33	1.70
31	28.8	16.02	9.18	5.10	3.45

[a] 0.083 hr oxidation.

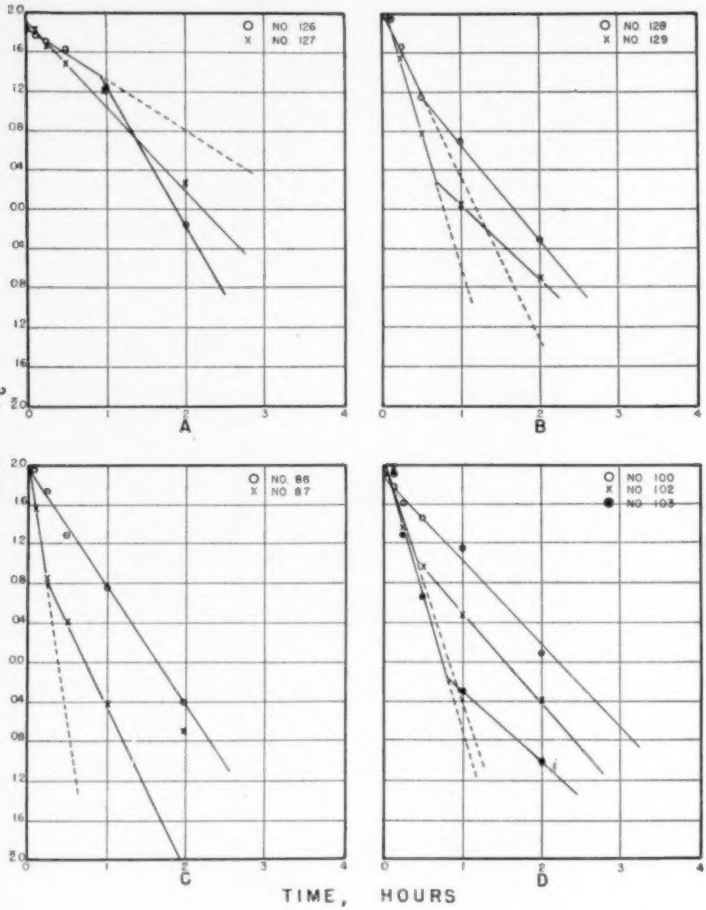


Fig. 7—Logarithm of concentrations of "coal" plotted against time of oxidation.

(A) Two light specific gravity fractions of +1-in. Clements bed coal. *(B)* Two heavy specific gravity fractions of +1-in. Clements bed coal. *(C)* Two specific gravity fractions of —No. 4, +No. 8 Clements bed coal. *(D)* Three specific gravity fractions of —No. 4 + No. 50 Clements bed coal.

concentration and the second, or straight portion, reflects a zero-order reaction in which the rate is independent of the concentration. Early in the process, the first-order oxidation of "coal" will predominate and the overall rate will be governed by it. When all of the "coal" is oxidized, the oxidation of the remaining material, which is fusain, will follow the zero order law.

The reaction rate for the coal fraction then will be:

$$\frac{-dC_c}{dt} = K_cC_c \qquad [1]$$

in which C_c represents the concentration of coal at time t and K_c is the specific reaction rate. After integration, eq. 1 becomes

$$K_c = \frac{2.303}{t} \log \frac{C_{c_0}}{C_c} \qquad [2]$$

in which C_{c_0} is the initial concentration of "coal" and t is in hours; K_c is in units of percentage points per hour.

Results of the Oxidations: The condition noted initially and which led to the closer study of oxidation rates of various specific gravity fractions, was that reaction rates increased with decreasing density of the fraction as is clearly shown in table III. At the same time it was noted that the "brightness" of the fractions increased with decreasing density. No attempt was made to assess "brightness" qualitatively by determining relative numbers of "bright" and "dull" particles but the generalization was based on appearance only. In some cases, as for example samples No. 87 and 88, the ash content of both fractions was low but the differences in "brightness" were striking.

The value of K_c at 0.125 hr was generally lower than its value at 0.25-hr oxidation for Clements bed samples. Without exception, the maximum specific reaction rate occurred at 0.125 hr for all fractions of all the lower rank coals. These facts indicate that the higher rank Clements coal was comparatively slow to begin oxidation. Sample No. 87, although of comparatively high rank, oxidized much like the lower rank coals. All lower rank fractions exhibited high initial specific reaction rates.

The samples of natural, raw size fractions showed the same variations as were shown by the float-and-sink fractions but they generally had a wider range of values for K_c than any single specific gravity fraction. This undoubtedly was due to the greater heterogeneity of their petrographic composition.

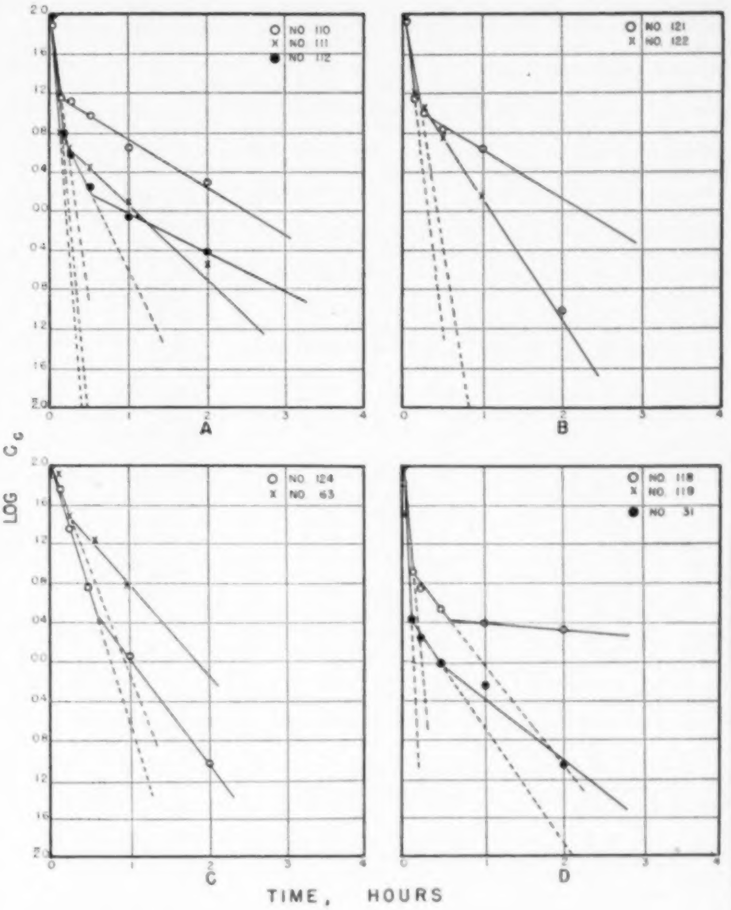


Fig. 8—Logarithm of concentrations of "coal" plotted against time of oxidation.

(A) Three specific gravity fractions of —No. 4 +0 Milldale bed coal. (B) Two specific gravity fractions of —No. 4 +No. 50 Black Creek bed coal. (C) —No. 50 +0 +1-in. Clements bed raw coal. (D)—No. 50 + No. 200 and —No. 200 raw Black Creek bed coal and raw Clarke County lignite.

The rather wide variations in the values of K_c for different oxidation intervals differ from the findings of Fuchs and associates.[3] They point to the fact that for the three coals on which they had complete data, K_c was fairly constant. Their fig. 4, in which log C_c was plotted against time, exhibits a straight line relation. They say, "the straightness of the log C versus time lines and the constancy of the values of K_c vary from coal to coal, in no way conflicts with the assumption of a first-order mechanism. It is fully realized that 'coal' is a mixture of petrographic components and that the relative proportion of these components will vary from sample to sample." Figs. 7*A*, *B*, *C*, and *D* and 8*A*, *B*, *C*, and *D* show that log C_c versus time does not always yield a straight line but that at least two straight lines with differing slopes are often required to satisfy the points. In spite of these differences, this worker believes that the views of Fuchs and associates, quoted above, are essentially correct for coals containing very large proportions of one pure "coal" component. The very departures from the relationships that were suggested by them may serve as a basis for an approximation of petrographic composition.

For some coals it is possible that the nonfusain "coal" material is uniform in composition, that is, it contains essentially but one component. In this case one should expect a constant value for K_c and a straight line for the time-log C_c relation. If two or more components are present and all have substantially the same reactivity toward nitric acid, the time-log C_c relation again should yield a straight line. If, however, two components having widely differing reactivities are present, two straight lines would be needed to satisfy all the points. If there are a great many components or if reactivities are similar, a curved line changing gradually in slope should be expected. In figs. 7 and 8, all three of these types of arrangement are suggested for one or more samples. The fact that, in most cases, two lines seem to satisfy the points best and the rather sharp changes in directions are observed, strongly suggests differing reactivities toward nitric acid. Fig. 8c illustrates a possible interpretation of the meaning of single lines or intersecting segments. Sample No. 88, representing the float 1.60-sink 1.28 fraction, apparently has only one component with regard to reactivity toward nitric acid. The second point does not fit the line drawn very well, indicating a slow start for the oxidation action. Sample No. 87,

representing the float 1.28 material, is evidently multicomponent. The first three points fit a line with a very steep slope. The last of these points and the next two fit another line with a smaller slope, only a little greater than the slope of the line drawn for sample No. 88. The last point fits neither line and is close to the last point of No. 88. Some of the points do not fit perfectly the lines drawn, but there are enough good fits to establish the presence of definite changes of direction. The oxidation rate of the more reactive component evidently governs the overall rate early in the period but after it is reduced to a small concentration, the average rate becomes very nearly that of the less reactive component which remains in considerable quantity.

Table IV. The Percentage Present and the Specific Reaction Rate of Each "Coal" Component

Sample No.	$C_{c_{o-1}}$	$C_{c_{o-2}}$	$C_{c_{o-3}}$	C_f[a]	K_{c_1}	K_{c_2}	K_{c_3}
126		42	[b]	33		1.1	
127		74		26		1.9	
128	49	45		6	3.8	2.2	
129	93	6		1	5.9	1.7	
88		95		5		2.8	
87	82	17	[c]	1	11.2	3.6	
100		82		18		2.0	
102	72	25		3	5.5	2.1	
103	97	2		1	6.2	1.7	
110	66	16		18	13.8	1.1	
111	90	7		3	22.0	1.7	
112	88	8	2	2	20.8	3.7	0.9
121	75	13	[c]	12	10.5	1.2	
122	73	24	[c]	3	15.0	2.8	
63	36	51	[c]	13	4.7	2.1	
124	86	10		4	5.8	2.4	
119	33			67	20+		
118	59	7	3	31	17.4	7.5	0.1
31	95	2	2	1	32.1	5.3	1.9

[a] Concentration of fusain, pct.
[b] Quantity of heavier fractions of No. 126 not determinable by this method.
[c] A small quantity of less reactive material is represented by a point at 2 hr oxidation or with a concentration at 2 hr so small that its logarithm is less than $\bar{2}.00$.

It is quite probable that the composition of even a narrow specific gravity range of a coal is somewhat more complex than one, two, or three intersecting lines can represent accurately. It is of assistance, nevertheless, to be able to detect the presence of two or more distinct components with differing average reactivities even if each phase itself has a composition of considerable complexity.

The method of extrapolation, to zero time, of the flat portion of each complete oxidation curve to determine the percentage of fusain suggests the same procedure for the other coal components. Figs. 1 to 6, which are drawn with linear coordinates, are not suitable for this purpose as the oxidation rate of the "coal" components is not linear with respect to time. Figs. 7 and 8, however, are suitable since the log of the rate of change in concentration of any given component is linear with respect to time.

Assuming that C_{c_o} represents the concentration of all "coal" components in the original, dry, ash-free sample at zero time and not just the concentration of component $C_{c_{o-1}}$, and that the intersection of the zero time ordinate by the second straight line portion of the curve represents the concentration of the second most reactive component of the coal plus that of all less reactive components, the values for $C_{c_{o-1}}$, $C_{c_{o-2}}$ and $C_{c_{o-3}}$ in table IV were calculated. The values given are the concentration of each component, shown in figs. 7 and 8, at zero time, or the percentage of each in the original dry, ash-free coal. The specific reaction rates shown for each component in table IV were calculated from eq. 2 with the values of log $C_{c_{o-2}}$ and log $C_{c_{o-3}}$ read from figs. 7 and 8. Log $C_{c_{o-1}}$ at times other than zero was also read from figs. 7 and 8. To give a sum of 100 pct for all components of the dry, ash-free coal, values for the concentration of fusain at zero time, C_f, are given.

A study of table IV will show that successively lighter specific gravity fractions are made up of increasingly more reactive material, or of decreasing quantities of material of approximately the same reactivity as that composing the heavier fractions. Samples No. 87 and 88 illustrate a case of rather simple composition. No. 88 is made up of 5 pct fusain and 95 pct of a component having a specific reaction rate of 2.8 pct per hr. No. 87 is composed of 1 pct fusain, 82 pct of a component with a reaction rate of 11.5 pct per hr, and 17 pct of a component with a reaction rate of 3.6, or only a little greater than the rate of the entire "coal" component of No. 88. In addition to the two components shown, a small quantity of material (less than 1 pct), represented by the point at 2 hr oxidation, is included in the second component.

Samples No. 100, 102, and 103 illustrate a case of decreasing quantities of the "dull" component and increasing quantities of the "bright" component. No. 100 is "dull" coal with a specific reaction rate of 2.0 and is associated with 18 pct of fusain. No. 102 contains 72 pct of another component having a much higher specific reaction rate of 5.5, and 25 pct of practically the same component as the "coal" portion of No. 100. Finally No. 103 contains 97 pct of the "bright" component and only 2 pct of the "dull" one.

In samples No. 121 and 122, the content of "bright" coal is the same in both samples but the percentage of the "dull" is, quite unexpectedly, a little larger in the "bright" fraction. It will be observed, however, that *both* components are much more reactive in the lighter fraction than in the heavier one.

It will be noted that the "bright" and "dull" components delineated by oxidation are not precisely identified with the familiar components of coal petrography. If there is a correspondence between "chemical" and petrographic components of "coal" and "chemical" and petrographic fusain, it should be revealed by a careful quantitative study of several coals by both methods. Undoubtedly, the more reactive component of sample No. 87 was essentially vitrain and probably the least reactive one was durain or opaque attritus. Where intermediate components appear, they probably represent attritus of varying degrees of translucency. The relative proportions of "chemical" components shown in this study do not substantiate the existence of an entity fitting the description usually given to clarain but suggest that clarain is a mixture of "bright" and "dull" components.

An inspection of the specific reaction rates of the heavier fractions of several coals in table III reveals a peculiar trend right at the end of oxidation of the "coal" portion. Samples No. 126, 127, and 121 show a slightly lower specific reaction rate for 1 hr of oxidation than for 2 hr. The same thing probably would have been true for No. 63 had not all the "coal" been oxidized in less than 2 hr. The condition was so pronounced in the case of No. 126, that fig. 7*A* clearly shows an increased slope for the second component over that of the first. If the second component be extrapolated to zero time, it

appears to exceed 100 pct of the sample. This condition was not an accident of analysis because the entire curve was rechecked (data not shown) with the same result.

Such a condition clearly is impossible if the thesis supported thus far is true, namely, that the more slowly oxidizable components govern the apparent oxidation rate near the end of "coal" oxidation. The only explanation which appears to be at all satisfactory is that part of the material oxidized during the last hour, in the case of some heavier fractions, does not follow the first order reaction law of eq. 2. On the assumption that the material was similar to fusain, reaction rates were calculated using the zero order reaction law which governs the oxidation of fusain.[3] In all cases, the rates were much larger than those for fusain in the same sample, but they decreased steadily with a decrease in the dry, mineral-matter-free fixed carbon content (rank) of the sample. As extrapolation of a line connection 1 hr and 2 hr oxidations on fig. 1 would give much too large a percentage of this intermediate material, it appears likely that the actual oxidation rate law governing this portion of "coal" may be quite complex and follow neither zero nor first order. If this is true, fusain may not be a sharply distinct component of some coals but they may contain, in addition to true fusain, some materials which are so "dull" as to be semi-fusainized.

It was reasoned that if the quantities of the various components shown in table IV represented approximately the true composition of each sample, a weighted average reaction rate for all components should be very nearly the same as average rates calculated from table III, weighted as to time. Both average rates and the algebraic differences are shown in table V.

Differences were quite small for Clements coal but for all coals of lower rank (including sample No. 87 of Clements coal) they were large. Except for Clements bed coal, table V can not be considered a confirmation of the compositions calculated for table IV. A comparison of the values in the difference column, table V, with the corresponding fixed carbon percent, table II, shows that the difference generally increases with rank. Samples No. 121, and 122 show smaller differences than their ranks indicate they should, while No. 87 and 88 show larger ones.

Specific Oxidation Rates and Rank: It is apparent from a comparison of tables II and III that the rate of reaction of coals with nitric acids is influenced by the rank of the coals as well as by the nature of their physical components. A study of the oxidation data regarding the relation of rank and reactivity was made.

For all bituminous coals above high volatile bituminous A rank, the sole basis for rank determination in the Standard Specification for Classification of Coals by Rank, of the ASTM, is the dry, mineral-matter-free fixed carbon.[7] With the exception of the lignite sample, all coals included in this study were of high volatile A rank or above, so that the fixed carbon contents, calculated with the Parr formulas as required in the Standard Specification, have been used as the basis of rank. Fixed carbon content, of course, may not be the best criterion of rank. The presence of much fusain, which is almost always higher in fixed carbon than the associated "coal," may give some coals a higher rank than other properties indicate they actually have. Total carbon content probably would have no advantage over fixed carbon, for purposes of rank determination. If a clear and explicit relation between rank and nitric acid oxidation rate could be worked out, the latter might prove more suitable than fixed carbon content for rank classification purposes.

Values of K_c from table III and of the concentration of coal at various times of oxidation were plotted against dry, mineral matter-free fixed carbon. Heating values calculated to the same basis were also tried. The composition-weighted averages from table V, plotted as a function of fixed carbon, gave an S-shaped curve with the lower inflection of the S occuring near 73 pct fixed carbon and a similar plot of the time-weighted averages was fitted fairly well by two line segments of differing slopes intersecting at about 70 to 72 pct fixed carbon.

The best distribution of points was given by values of K_c at 0.25-hr oxidation and by values of the concentration of "coal" remaining after 0.25-hr oxidation, plotted against fixed carbon. These relations are shown in figs. 9 and 10. It is readily seen that there is a considerable scattering of points in both cases. That the scattering is much greater for the "bright" coal fractions, particularly of the lower rank coals, is apparent. If the solid lines drawn are accepted as best fitting the points, fig. 9 indicates a change of about 0.77 pct per hr in specific reaction rate per percent of fixed carbon for the lower (high rank) portion of the curve and about 1.9 pct per hr for each unit of fixed carbon for the low rank portion. In fig. 10, a decrease of about 3.9 pct in the concentration of "coal" after 0.25-hr oxidation for each percentage increase in fixed carbon, is indicated.

Table V. Composition-weighted and Time-weighted Specific Reaction Rates Compared

Sample No.	Avg. K_c[a] Composition	Avg. K_c[b] Time	Diff.
126	1.1[c]	1.7	— 0.6
127	1.9	1.7	+ 0.2
128	3.0	2.8	+ 0.2
129	5.6	3.7	+ 1.9
88	2.8	2.8	0.0
87	< 9.9	5.3	< + 4.6
100	2.0	1.7	+ 0.3
102	4.6	3.3	+ 1.3
103	6.1	4.3	+ 1.8
110	12.2	3.5	+ 8.7
111	20.5	5.6	+ 14.9
112	18.8	5.7	+ 13.1
121	< 9.1	5.5	< + 3.6
122	< 12.0	6.4	< + 5.6
63	< 3.2	2.6	< + 0.6
124	5.4	4.1	+ 1.3
119			
118	> 15.6	4.1	> + 11.5
31	30.9	6.9	+ 24.0

[a] Average weighted by percentage of each "coal" component, table IV.
[b] Average weighted for length of interval, table III.
[c] For first component only.

Black Creek bed coal shows little evidence of a dependence of reactivity upon rank. The independence of rank shown by the particular low rank coals studied may be partially accounted for by the very low proportion of "dull" material present, as shown in table IV. The "bright" fractions of Clements bed coals, samples No. 87, 103, and 129, exhibit widely differing reactivities although they are almost identical in rank. Of the three, sample

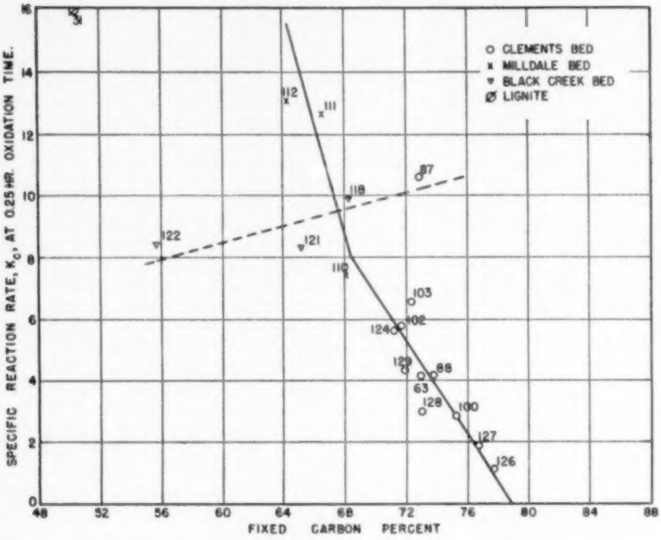


Fig. 9—Specific reaction rate at 0.25-hr oxidation time as a function of dry, mineral-matter-free fixed carbon (rank).

No. 129, the "bright" fraction from the higher rank, plus 1-in. size range, conforms most closely to the general trend indicated by the solid lines in figs. 9 and 10.

It is obvious, then, from the preceding discussion that the higher the rank the more definite the relation between rank and oxidation reactivity. This is confirmed by a private communication from C. C. Wright. Concerning unpublished work of a similar nature done at the Mineral Industries Experiment Station at the Pennsylvania State College, he says, "I believe that if the interest is limited to coals of a given rank something could be worked out. The higher the rank the more probability of definite correlations being developed judging by the rather limited results we have on record."

It must be concluded from this part of the study that no general criterion can yet be proposed for untangling the effects of rank from those of variations in petrographic composition, except in the case of coals or fractions having practically the same rank. Study of a larger number of coals and specific gravity fractions of coals of the lower ranks will be necessary if any general rank-oxidizability relation is to be found.

Suggested Uses: In addition to the possible use of oxidation data for determining approximate quantities of some petrographic components in coals, it should yield valuable information as to the suitability of coals for different purposes. Fuchs and associates[2] seemed to get the same relative orders of reactivity as are reported in this paper by the use of some slightly different oxidizing agents. Rees, Wagner, and Tilbury found that reactivity indexes obtained by the C.R.L. test generally increased with rank, indicating decreasing reactivity.[8] They found no definite trend in reactivity with respect to petrographic composition but suggested that the C.R.L. test probably measures more nearly the reactivity of the most active component in a mixture. This was confirmed when they found an increase in the reactivity indexes of fusain from which the more reactive components had been removed by boiling in nitric acid. It should be stated that highest rank coal tested by Rees and associates was about the equivalent of the Black Creek coal of the present study, and that rank and petrographic composition effects are, as has been shown in this study, more difficult to untangle for the coals of lower rank.

Oxidation rate data should be useful in the evaluation of size and specific gravity fractions of a given coal as to relative suitability for direct hydrogenation. The Bureau of Mines[5] found essentially the same relation between rank and petrographic composition and amenability to hydrogenation as is reported in this paper for rank and petrographic composition with regard to reactivity toward nitric acid. Values of K_c calculated from oxidation rate data should be even more useful than rank for this purpose. If a coal contains considerable "splint" coal in bands, or disseminated, the specific gravity at which splint would be largely eliminated could be determined without much trouble. Lessing[9] has suggested that the "bright" portion of banded coal is more likely to be coking than the dull fraction. Oxidation data should indicate roughly the proportion of "bright" coal suitable for blending for coke, that could be expected from any specific gravity or size fraction of a coal of the proper rank, even if the whole coal were not quite suitable for that purpose.

Summary

One medium volatile bituminous and two high volatile A bituminous coals were separated into specific gravity fractions and samples of each fraction were oxidized in 8 N nitric acid for seven different periods of specified length. In addition to the determination of fusain content, studies were made of the first five oxidation periods during which nonfusain "coal" material was oxidized. Two raw samples each of the medium volatile bituminous, and the lowest rank high-volatile bituminous A coals, and one raw sample of lignite, were also studied.

The quantity of dry, ash-free residue at the end of any given oxidation period was found to decrease

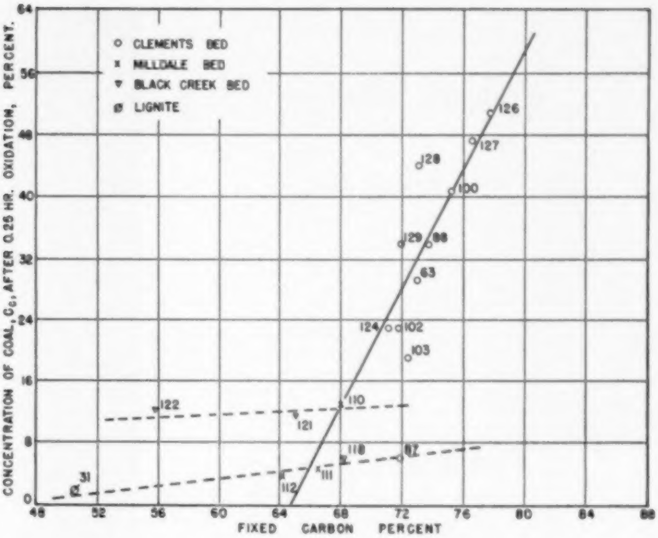


Fig. 10—Concentration of coal after 0.25-hr oxidation as a function of dry, mineral-matter-free fixed carbon (rank).

and the specific reaction rate was found to increase with decreasing density of the fraction.

When the logarithms of "coal" concentration were plotted against time, for a few of the heavier fractions, all points fell on or near one straight line; in nearly all other cases, two straight lines with considerably different slopes were sufficient to satisfy all points.

Extrapolation of the line segments to zero time on log C_c-time plots, yielded estimates of the percentage of each coal component present. The specific reaction rate of each component was readily calculated.

A very close relationship between rank and both concentration of "coal" and specific reaction rate at 0.25-hr oxidation was found to exist for the medium volatile and the higher rank high-volatile A bituminous coals but the relationship was not clear for lower rank coals. The specific reaction rates for the very "bright" fractions seemed to be more nearly independent of rank than the rates for the other fractions.

In addition to the possibility that the method can be used to estimate the quantity and chemical reactivity of the different petrographic components in a given coal, it may yield valuable information as to the suitability of various coals or size and density fractions of the coals, for many chemical uses. Specific reaction rates might prove a more superior criterion of rank, in many cases, than the present chemical analysis.

Much more work remains to be done before the relative effects of petrographic composition and of rank upon specific reaction rates can be untangled. Extensive studies will be required also in order to make positive correlations of components determined chemically and the petrographic components commonly recognized optically.

Acknowledgment

The author wishes to acknowledge his indebtedness to Robert D. Brown of the Department of Chemistry, University of Alabama, who read the paper from the standpoint of the physical chemist. C. C. Wright, along with C. R. Kinney, T. S. Polanskey, and H. B. Charmbury, all of the Fuel Technology Department of the Pennsylvania State College, read the paper in a more primitive form. They made many invaluable suggestions, practically all of which are included in the paper in its present form.

Finally the author wishes to acknowledge the valuable assistance of E. L. Thomas, Jr., now of the Tennessee Coal, Iron and Railroad Co. All analyses were made by him with great skill and care. To him should go much credit for the consistent and reproducible data obtained from a tedious and difficult determination.

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Wrapping Pillars With Old Hoist Rope

by B. T. Wykoff

Completed pillar before rope clamping on solid side of open eye bolts.

This paper describes an important function of mining in Southeast Missouri. The practice is a necessary procedure to prevent disintegration of the pillars. Although the technique is peculiar to this district, it might have application in other mines using room and pillar method.

CONSIDERING the subject alone, this paper would cover only a mechanical treatise of pillar roping. Because the St. Joseph Lead Co. originated the practice, it is proper to give a short introduction to the company. It is also proper to describe pillars and discuss their purpose to justify expending large sums of money to preserve them after the surrounding area has been thoroughly mined.

Because the St. Joseph Lead Co. originated the practice of back pinning with wedge bolts, patch plates and channel irons, and the pouring of substitute pillars of concrete, these too, are mentioned.

The Southeast Missouri Division of the St. Joseph Lead Co. is the largest lead producer in the United States. About 95 pct of the present producing mines are in St. Francois County, which begins 60 miles south of St. Louis. The entire lead ore production of this county, at the present time, is mined and milled by this company, treatment plant capacity being about 22,000 tons per day.

This area is also the oldest, lead having been mined at Mine La Motte, in Madison County, in 1723. Estimated production of all the various companies that have mined here is about 7,000,000 short tons of pig lead.

Method of Mining

The lead occurs in the ore as galena. Galena is found either in the form of disseminated or solid streaks, of varying thickness. Ore stratum is the Bonne Terre dolomite, which is about 350 ft thick, but almost all the ore is in the lower 100 ft. Ore is mined by room and pillar method in open stopes. These stopes vary in height from 7 ft to 200 ft, depending on the thickness of the pay ore in that spot. Back, or roof, is supported entirely by pillars. In a majority of stopes, after the loose scales are mined down, the back has remained solid for many years (fig. 1).

Under ideal conditions pillars are spaced to form an equilateral triangle and are as small and as far apart as the height of the stope and the character of the back will permit. They vary in diameter from 10 ft to 50 ft and are from 18 ft to 50 ft apart, measured from the outer edges. In general, the pillars are approximately 12 ft in diameter, and 25 ft apart. The spacing is very uncertain because of the vagaries of the ore trend, the desire to better support breaks in the back, and the attempt to spot out the thinner ore by not placing one in the core of the ore body.

Use of Structural Steel Channels

In stopes where the back is bad because the overlying formations are thin with wet, weak and shaly

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AIME Columbus Meeting, September 1949.
TP 2906 A. Discussion (2 copies) may be sent to Transactions *AIME before Sept. 29, 1950. Manuscript received Sept. 15, 1949.*

Fig. 1 (left) — Room and pillar mining. In most stopes, the back has remained solid for many years.

Fig. 2 (right) — Channel iron in backing. Wedge bolts with patch plate washer stop peeling in loose areas.

Fig. 3 (left) — Concrete pillars. Concrete pillars substituted for normal pillars allow removal of old pillars in rich areas.

Fig. 4 (right)—Split pillar. Pillars weather and dry out, and shifts cause cracks and sluffing.

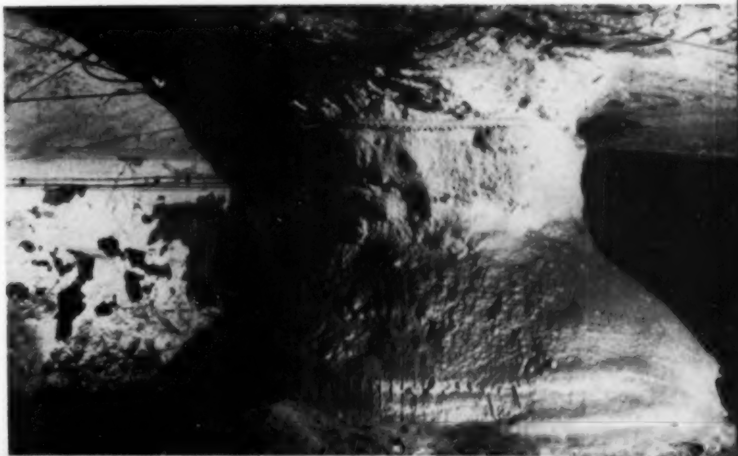

Fig. 5—Hour glass pillar, fenced and gunited.

Fig. 6—Irons on split pillar.

ore body. After the back and bottom have been thoroughly prospected for secondary ore and none found, slabbing is done for partial pillar recovery. This practice is unsatisfactory if the whole pillar can be recovered later. In one mined-out area of rich ore, some substitute pillars of concrete were poured between the old pillars. This allowed complete removal of the pillars but is economically satisfactory only in rich areas (fig. 3).

Some safe and economical method will be developed, and the pillar recovery program can become an important part of mining. Until that time, the old mined-out areas have to be inspected regularly and the old pillars guarded carefully, not only for the safety of men working in the secondary ore and the main lines running through these old stopes, but to see that no area is lost from cave-ins due to pillar failure, thereby losing forever the recoverable ore in the failed pillars.

Maintaining safe back is no problem provided the pillars remain intact. However, if the pillars start taking weight, splitting and cracking, spalling off slabs or if certain mineral bands disintegrate within, the problem is acute and immediate.

Splitting, cracking, and spalling off slabs are caused by minute vertical seams and slips which, at the time the pillar was formed, were filled with live mineral of high moisture content. The pillar at this time was more or less elastic and able to withstand high pressures and side thrusts without visible effect. However, after standing for several years in natural ventilation currents of varying temperatures and humidity, the pillars weather and dry out. The mineral seams no longer are adhesive, the least shift causes cracks and sluffing. The mineral bands, mainly galena and pyrite, oxidize and become soft, slimy material (fig. 4).

The glauconite and shale bands shrink and laminate; finely divided particles separate; and the pillar assumes definite hour glass shape. First stages

seams, or are split vertically by slips and faults, additional support is needed, and this is adequately provided by the use of 4 in., 6½ lb structural steel channels. These channels are pinned flat against the back by 1 in. round mild steel threaded wedge bolts 10 to 12 ft long, in holes drilled on a 45°, about 3 ft apart, which reach up into a solid layer. End holes are drilled over the tops of pillars; the irons are of any length and are spaced any necessary distance apart. By the use of an impact wrench, nuts are drawn up tightly on an angle washer placed in the web of the iron. When properly driven, these rods have tested 20 tons each before slippage, elongation, or breakage. If the loose area is small, a single wedge bolt in a vertical hole, using a patch plate washer, has been sufficient to keep the back from peeling (fig. 2).

Pillars represent millions of tons of potential ore reserves. They contain about 10 pct of the original

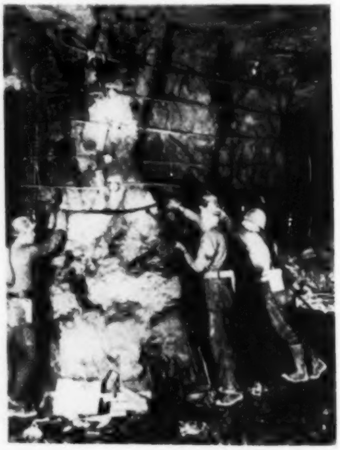

Fig. 8—Pillar roping in action.

Fig. 7—Patch plates on pillar which later required roping.

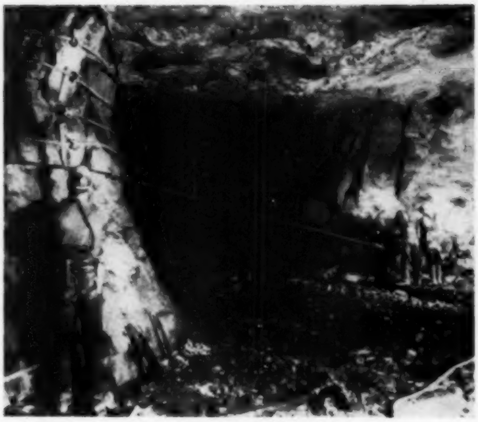

Fig. 9—Pillar roping in action.

of disintegration have started, and mechanical assistance is needed to prevent complete loss (fig. 5).

Starting at the focus of trouble, where the pillars are the worst, the salvage campaign is put under way. Preliminary to rehabilitation, the pillars are prepared by removing all small spalls and pieces which are not necessary. If the loose is large and the pillars small, the pieces may be held together by tie-rods, threaded on each end, placed in holes drilled completely through the pillar and the nuts drawn up tightly on patch plates. If the pillars are large, these rods can be wedge bolts, long enough to reach the solid section of the pillar, and the patch plates can be channel irons placed vertically on the sides or circled around as in banding. If the ground in the area is not too heavy, and deterioration of the pillars not too far advanced, the use of these strengthening devices is usually sufficient to retard failing indefinitely. On the other hand, if the ground is heavy, and is an important area from standpoint of plant and rich ore, and is required to be safe for the future mine, then it is best to resort to wrapping (figs. 6 and 7).

Hoist rope in the district varies from 7/8 in. to 1 5/8 in., depending on whether the shafts are used only for man cages, exclusively for ore skips, or for a combination of cage and skip. Minimum factor of safety for men is 7.5, for ore 3.2, and both go as high as 12.0. Ropes are changed when they have been in use 3 years or when their strength has lowered to 80 pct of catalog value, other conditions such as lubrication and usage being normal. From this, it may be deduced that although a rope has been discarded for hoisting it may be in excellent condition for other uses, the most important of which has been underground on pillars.

Fig. 10—Come-a-long, chain hoist, and auxiliary tugger

Fig. 11—High traps.

The rope sizes most available are 1 1/8 in. and 1 1/4 in. These still have breaking strength of 30 to 40 tons. After winding on the old reels, they are sent underground to the area in need. Here they are placed on supports to facilitate unwinding. Several loose turns are made around the base of the pillar, using an air powered tugger hoist, if available, in order to eliminate heavy dragging. Pillar roping then begins with the first hole being drilled into the pillar close to the top. Into this hole is driven a welded eye wedge bolt. Fourteen inch is standard length. Through this eye the loose end of the rope is threaded and doubled back, being firmly secured with proper size rope clamps. New holes are drilled down the side of the pillar, in carefully selected, solid spots, one hole for each foot of vertical drop. These holes should not be in a vertical plane, but at an oblique angle. If the vertical plane were a weak section, all these holes might

Fig. 12—Properly roped pillar with back channels and patch plates.

split the pillar under pressure. Into these holes are driven open eye wedge bolts. All these bolts are about 14 in. long and 1 in. round mild steel. Each turn of the rope, one at a time, is laid in its corresponding open eye, a come-a-long clamped on the loose end onto which is hooked a 10-ton Coffing chain hoist, the tail hook of which is securely fastened to a bolt in the floor or a neighboring pillar. On high pillars it is best to get the tail high for a straight-away pull (figs. 8, 9, and 10).

In pulling the rounds tight, care is exercised to place the rope around to the best advantage in order to cover cracks and to pull slabs in tightly. On sharp angles a sledge hammer is used to make the rope conform to the contour of the pillar. As each turn is completed, and while the pull is still on, a rope clamp is fastened on the pull side of the open eye. Turn after turn is secured on down the pillar. Ropes are made continuous easily by overlapping and clamping. About every third turn a rope clamp is locked on the solid side of the open eye. These clamps serve a dual purpose; they not only make it possible to tighten each wrap individually, but also, should any rope break, they would prevent its unraveling the full length of the pillar. At most, only three rounds would be lost, as the remainder still would be held securely by the clamps and eye bolts as shown in title photograph.

Work on pillars up to 35 ft high can be done by using sectional ladders. Trapeze or suspended platforms are required above 35 ft. These traps are run out to the pillar from a neighboring high breast. Work below is facilitated by a boatswain's chair or ladders dropped down from the traps (fig. 11).

In early practice, wooden wedges were driven between the rope and pillar. The use of these has been discontinued because of the instability of the wood over long periods. Chicken wire also has been placed over the completed pillars and the whole covered with a coating of gunite. This is an unnecessary expense because, although guniting is excellent to prevent oxidation and disintegration, it should be applied before the trouble starts.

Costs were recently kept on a series of pillars 18 ft high and 14 ft in diameter requiring 15 rounds per pillar 45 ft in circumference. Three men wrapped 6 pillars in 6 weeks, 30 working days or 90 man shifts.

Time includes getting material to the area and that consumed in roofwork.

Per Pillar:

Rope, 675 ft @ \$0.05 equals \$33.75 (rope cost is surface labor wind on reels and send underground). Clamps, 23, 1⅛ in. @ 0.85, \$19.55. Eye bolts, 17, @ 0.30, \$5.10. Wedges, 17, @ 0.06, \$1.02. Total material, \$59.42. Total labor, \$186.20. Total cost per pillar, \$245.62.

Properly roped pillars need no extra precaution for a long life (see figs. 12, 13, and 14).

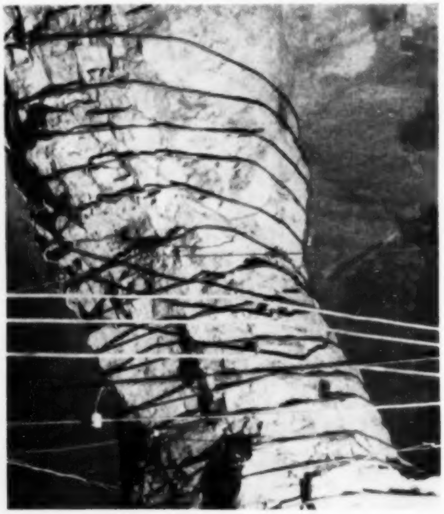

Fig. 13—Properly roped pillars over ten years old.

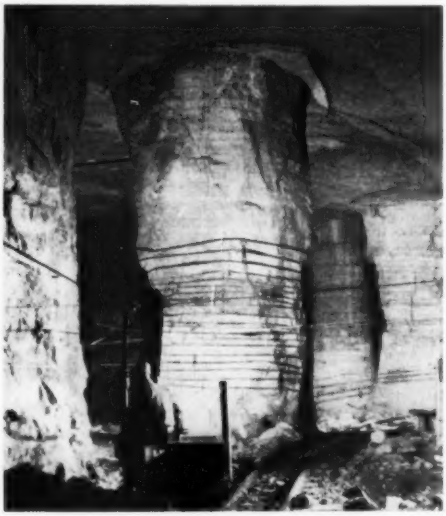

Fig. 14—Roped and concrete pillars in same area.

aime NEWS

1951 Mexico City Meeting

Formal acceptance of an invitation to hold the Fall Meeting of the AIME in Mexico City in October 1951 was voted by the Board at its meeting on June 22. The invitation was first tendered at the Annual Meeting last February, by Ing. Raul de la Pena, director general of the Instituto Nacional para la Investigacion de Recursos Minerales. Several other societies covering the mineral technology field have also been invited by Mr. de la Pena to participate.

This will be the first AIME meeting to be held outside of the United States since the 146th meeting, which also was held in Mexico City, in November 1936.

Geophysics Sub Broadens Scope

Consideration of the scope of the Geophysics Subdivision of the Mining, Geology, and Geophysics Division of the Institute was brought before the Board at its June 22 meeting. Subjects to be covered include the application of geophysical engineering techniques not merely to metal mining but to exploration for nonmetallic minerals, to the measurement of overburden, to the location of limestone, gravel, and other deposits not exposed at the surface, to the search for water supplies, and the mapping of the water table. Excluded will be investigations in general geophysics not of an engineering nature.

Western Secretary Appointment Imminent

Further progress in establishing a Western Secretary for the Mining Branch of the AIME was made at the June 22 Board meeting and it now seems likely that the office will be established on at least a part-time basis within the next few months. The Secretary of the Institute was given authority to secure a suitable man for the position, and to set up the office, probably in Salt Lake City, provided the expense of so doing could be kept within the budget for the Mining Branch in the current year.

Policy on Controversial Matters Liberalized

Liberalization of the Institute's policy on controversial matters was voted by the Board at its meeting on June 22. Some members of the Institute had felt that the policy heretofore followed had been too narrow. Recently (Feb. 12, 1950), the Executive Committee of the Mineral Economics Division had specifically asked the Board to endorse a proposed resolution whereby the Board could make known "facts and views on matters affecting the mineral economy of the nation . . . relating to national defense, provision of adequate peacetime mineral supply, and conservation and development of mineral resources." The Board did not wish to go as far itself as was suggested by the Mineral Economics Division, but at its June 22 meeting passed the following resolution:

WHEREAS, one of the purposes of the American Institute of Mining and Metallurgical Engineers is, according to its constitution, "to promote the arts and sciences connected with the economic production of the useful minerals and metals, and the welfare of those employed in these industries by all lawful means"; and

WHEREAS, The Mineral Economics Division of the Institute feels that the policy enunciated at the meeting of the Board of Directors on Feb. 21, 1933 "to refrain from official participation or action in controversial nontechnical economic subjects" is unduly restrictive; therefore be it

Resolved, That Branches, Divisions, and Local Sections of the Institute be encouraged to hold meetings, symposiums, and forums, and to publish papers in the Institute's journals as desired, for the objective discussion of subjects pertaining to the economic welfare of the mineral industry and those employed therein, both in the United States and abroad; and that reports of such discussions be made available as desired to public agencies; but that neither the Institute nor its Branches, Divisions, Local Sections, or official representatives shall adopt an official position on such matters. This, however, shall not be regarded as a rigid prohibition against an expression of opinion by the Board on matters pertaining to the mineral industries that are of vital interest to the nation in times of danger.

Reinartz Nominated to Board

Official announcement was made at the June 22 Board meeting of the selections made by the Nominating Committee for Institute officers for 1951, as published in the May issues of the three journals. A ninth candidate to add to the official ticket was selected by the Board, namely Leo F. Reinartz, assistant vice-president of the Armco Steel Corp., Middletown, Ohio, who was chosen for a three-year term as Director. Mr. Reinartz was born in East Liverpool, Ohio, Aug. 3, 1888. Carnegie Tech. granted him Bachelor of Science and Metallurgical Engineer degrees, and he has worked for the American Rolling Mill Co. and its successor, Armco Steel, ever since he graduated in 1909. Successively he has been chemist, assistant superintendent of open-hearth departments, open-hearth superintendent, assistant general superintendent and works manager. He was a Director of AIME from 1943 to 1948, serving as vice-president the last three years.

Extend J M Period for Vets

Veterans of World War II who have attended college following military service may apply for Junior Membership even if over thirty years of age provided they do so within a year after leaving school—not within three years. They may, however, retain their Junior Membership up to three years after such election, even though they are over 33 years of age.

Brownell Receives Rand Medal

The Rand Medal, awarded from time to time by the Board of Directors of the AIME for distinguished achievement in mining administration, was given to Francis H. Brownell at a dinner at the Engineers' Club, New York, following the June 22 meeting of the Board. The award, which was recommended by a committee of which Zay Jeffries was chairman, was scheduled for presentation to Mr. Brownell at the Annual Banquet but had to be postponed because of Mr. Brownell's enforced absence from the city.

The citation read: "For sound leadership in the administration of nonferrous mining and metallurgical enterprises and for outstanding contributions to society in financial and legal matters relating to the nonferrous metal industry." President McLaughlin presented the medal and certificate, and called upon several of the Directors and guests for remarks. Roger W. Straus, chairman of the board of the American Smelting & Refining Co., the office formerly held by Mr. Brownell, spoke in the highest terms of his former superior, stating that if the medal was given for great character, great ability, and great understanding, no one ever deserved it more than Francis H. Brownell. John C. Emison, chairman of the Finance Committee of AS&R, also an office formerly held by the medalist, likewise paid a tribute, as did R. F. Goodwin, vice-president in charge of mining. Mr. Brownell's son, Kenneth C. Brownell, president of the company, could not be present because of duties in the West.

Francis H. Brownell

Mr. Brownell made a stirring speech on the privileges of the American way of life.

Are You an Associate Member?

Many Institute members holding responsible professional positions are classed as Associate Members rather than Members. This is usually because of the fact that when they applied for membership their qualifications were not such that they could be elected as Members. To qualify for the latter category, one "must have had at least six years' employment in the practice of mineral engineering, or in the application of the sciences to any of the branches of the mineral industry, during at least three years of which he must have held positions of responsibility."

Associate Members are urged to apply for a change of status to Member as soon as they feel qualified. The prestige of being a Member well justifies the change. No cost is involved, and all fees and privileges are the same. Merely notify AIME headquarters that you wish to apply for the change in status and an application blank will be sent you. Or if you have one of the regular application blanks for membership, merely fill it out and mark it change in status.

Coming Events

July 30-31, Mining Assn. of Montana, Hotel Finlen, Butte, Mont.

Aug. 7-19, Chicago International Trade Fair, Chicago.

Aug. 28-31, American Mining Congress, Metal Mining Convention and Exposition, Fair Grounds, Salt Lake City.

Aug. 29, AIME, Section Delegates Meeting 4 p. m. followed by Board of Directors dinner and meeting, at 6 p.m., Pioneer Room, Hotel Utah, Salt Lake City.

Sept. 1, AIME, Minerals Beneficiation Division, Hotel Utah, Salt Lake City.

Sept. 3-8, American Chemical Society, National Chemical Exposition, Chicago Coliseum, Chicago.

Sept. 5-9, American Chemical Society, 6th national chemical exposition, Chicago Coliseum, Chicago.

Sept. 10-13, American Institute of Chemical Engineers, Radisson House, Minneapolis.

Sept. 15-16, National Society of Professional Engineers, Wheeling, W. Va.

Sept. 19-21, American Society of Mechanical Engineers, fall meeting, Hotel Sheraton, Worcester, Mass.

Sept. 20, AIME, Carlsbad Potash Section, Riverside Country Club, Carlsbad, N. Mex.

Sept. 22-23, AIME, El Paso Metals Section, Chihuahua, Chih., Mexico.

Sept. 28, AIME, Lehigh Valley Section, visit to Lehigh Navigation Coal Co., Lansford, Pa.

Oct. 3-5, American Institute of Electrical Engineers, Baltimore.

Oct. 5, AIME, Ajo Subsection, Ajo, Ariz.

Oct. 4-6, AIME, Petroleum Branch, Roosevelt Hotel, New Orleans.

Oct. 11-12, AIME, Industrial Minerals Div., Rocky Mt. Section, El Paso, Texas.

Oct. 12, AIME, El Paso Metals Section, El Paso, Texas.

Oct. 12-13, AIME, Southern California Section, Metal, Mining, and Petroleum Branches, Elks Club, Los Angeles.

Oct. 13, AIME, Southwestern Section, Open Hearth Committee, Iron and Steel Div., Houston, Texas.

Oct. 13-14, International Mining Days, El Paso, Texas.

Oct. 16-20, National Safety Congress and Exposition. Industrial safety sessions, Stevens, Congress, and Morrison Hotels; traffic safety, Congress; commercial vehicle, farm and home safety, La Salle; school, Morrison.

Oct. 17-20, AIME, Industrial Minerals Div., fall meeting, Norman, Okla.

Oct. 20, AIME, Eastern Section, Open Hearth Committee, Iron and Steel Div., fall meeting, Warwick Hotel, Philadelphia.

Oct. 20-21, Engineers' Council for Professional Development, annual meeting, Hotel Tudor Arms, Cleveland.

Oct. 22-24, American Mining Congress, metal and nonmetallic convention, Biltmore Hotel, Los Angeles.

Oct. 23-25, AIME, Coal Div., and **ASME,** Fuels Div., Hotel Statler, Cleveland.

Oct. 23-27 National Metal Congress and Exposition, International Amphitheater, Chicago. Participating organizations: AIME, Headquarters, Hotel Sheraton; ASM, Headquarters, Palmer House; American Welding Society, Headquarters, Hotel Sherman; Society for Non-destructive Testing.

Oct. 27, AIME, Southern Ohio Section, Open Hearth Committee, Iron and Steel Div., annual meeting, Deshler-Wallick Hotel, Columbus, Ohio.

Nov. 3, AIME, Pittsburgh Section of Open Hearth Committee, Iron and Steel Div., and Pittsburgh Section, AIME, annual meeting, William Penn Hotel, Pittsburgh.

Nov. 9, American Mining Congress, Coal Div. Conference, William Penn Hotel, Pittsburgh.

Nov. 14, AIME, Buffalo Section, Open Hearth Committee, Iron and Steel, Div., all-day meeting, Statler Hotel, Buffalo.

Nov. 16-18, Geological Society of America, annual meeting, Hotel Statler, Washington, D. C.

Nov. 26-Dec. 1, American Society of Mechanical Engineers, annual meeting, Hotel Statler, New York.

Dec. 7-9, AIME, Electric Furnace Steel Conference, Iron and Steel Div., Hotel William Penn, Pittsburgh.

Jan. 15-17, 1951, AIME, Minnesota Section, annual meeting. Mining symposium conducted by Center for Continuation Study, University of Minnesota.

Feb. 18-22, 1951, AIME, annual meeting, Jefferson Hotel, St. Louis. Metals Branch session to be held at the Statler Hotel.

Apr. 2-4 1951, AIME, Open Hearth and Blast Furnace, Coke Oven and Raw Materials Conference, Iron and Steel Div., Statler Hotel, Cleveland.

EJC Issues Sharp Criticism of Federal Water Policies

A committee of the Engineers Joint Council has submitted a report to President Truman and his Water Resources Policy Commission, that speaks out bluntly against "excessive and unsound" water resources practices. These practices were attributed to competing federal agencies and Congressional "response to pressure and trading," and the committee called for a halt in further authorizations until a uniform policy has been adopted.

The report deplored "ambiguous, uncoordinated and conflicting" Federal policies covering power, irrigation, flood control, navigation and other water resources projects. Although the report did not direct itself to the activities of any particular agency, it cited the fact that the Dept. of the Interior, Corps of Engineers, Dept. of Agriculture, Federal Power Commission, U. S. Public Health Service, Weather Bureau, Coast and Geodetic Survey "and many others" are concerned with one phase or another of water development.

The engineers offered specific recommendations for correcting the existing practices including methods of procedure, authorization, and economics. Copies of the report may be obtained from the AIME without charge as long as the limited supply lasts. If indicated on the request, in the event that the free supply be exhausted, the requests will be forwarded to Engineers Joint Council, which will supply copies for $1.50.

Section Delegates, AIME Board To Meet in Salt Lake City

The AIME Board of Directors will have a dinner followed by a meeting on August 29 at 6 p.m. in the Pioneer Room of the Hotel Utah. The Section Delegates of AIME will meet the same day at the same place at 4 p.m.

USBM Safety Trophy Awarded to American Zinc's Mascot Mine

Dr. James Boyd (front center) recently presented certificates for safety achievement to 206 miners and their supervisors at American Zinc Company's Mine No. 2 at Mascot, Tenn. The director of the Bureau of Mines earlier in the program had presented the bureau's Sentinels of Safety trophy (right foreground) to the Mascot mine for achieving the best 1949 safety record among underground metal mines. Supervisors and foremen receiving certificates for redistribution to their men are, standing from left: H. A. Coy, W. C. Armstrong, W. B. Davenport, P. R. E. Stair, W. A. Wyrick, L. V. Wagner, H. C. Morrell, C. W. Daniel and H. W. Childress. Howard I. Young of St. Louis, company president, is shown seated in right background. Another foreman, J. S. Marcum, received certificates for his men but does not appear in this picture.

Industrial Minerals Division Meets in Norman, Okla., October 17-20

The Fall Regional Meeting of the Industrial Minerals Division, AIME, is to be held in Norman, Oklahoma, October 17-20. Host for the meeting will be the Oklahoma Geological Survey; Dr. Robert H. Dott, Director of the Survey, is chairman of the local committee.

October 17 and 18 will be devoted to a program of technical papers which will highlight industrial mineral developments of the Southwest. Following the technical sessions, a two-day field trip in the Arbuckle Mountain area will be led by W. E. Ham of the Oklahoma Geological Survey. This field trip will visit active glass sand, dolomite, limestone, asphalt, and cement operations, other industrial mineral deposits and points of geologic interest.

Dr. Hugh D. Miser, Staff Geologist, U. S. Geological Survey, noted for tales of his native Arkansas hill country, will speak at a dinner meeting on October 17. His subject will be "Making a Geologic Map of Oklahoma"—a project in which he is currently engaged.

The Norman meeting is the first to be held in this general area and promises a varied fare of interest to people engaged in all phases of industrial production.

Mining Transactions Available

Transactions of the Mining Branch, AIME, for 1949 are now available. The price to AIME members is $3.50 and to nonmembers, $7.00. After Jan. 1, 1951, the price of this volume will be $7.00, less 30 pct for members, and $7.00 for nonmembers.

Metals and Petroleum transactions are also available at the same prices. The transactions are the technical material and articles, discussions, and technical notes contained in the transactions sections of the specific AIME Journals. Also included is an index.

This bound volume of transactions provides a permanent and continuing record of technical developments in the various fields covered by the activities of AIME. The attractively bound volumes will enhance anyone's technical library, and will serve as a ready and permanent technical reference.

Orders accompanied by checks may be sent to American Institute of Mining & Metallurgical Engineers, 29 W. 39th St., New York 18, N. Y.

AIME Magazines Available on Microfilm

The AIME has entered into an agreement with University Microfilms, Ann Arbor, Mich., to make available to libraries issues of *Journal of Petroleum Technology*, *Journal of Metals*, and *Mining Engineering* for 1950 in microfilm form.

Microfilm makes it possible to produce and distribute copies of periodical literature on the basis of the entire volume in a single roll, in editions of 30 or more.

Under the plan, the library keeps the printed issues unbound and circulates them in that form for from two or three years. Sales are strictly to those subscribing to the paper edition, and the film copy is only distributed at the end of the volume year.

The microfilm is in the form of positive microfilm, and is furnished on metal reels, suitably labeled. Inquiries concerning purchase should be directed to University Microfilms, 313 N. First St., Ann Arbor, Mich.

Look Again...

. . . at p. 813 of the July issue. Under the Division Nominations for the Extractive Metallurgy Division, it should say that O. Ralston, present Chairman-Elect, becomes Chairman in 1951, and T. D. Jones, Chairman Elect for 1951, will become Chairman in 1952.

The Drift of Things . . . . as followed by Edward H. Robie

Probably a Local War

Most students of the Russian situation seem to think that the Korean war will not extend beyond that country. If that proves true, the mineral industry need not anticipate more than a temporary fillip in the demand for its products. None of the controls and allocations of World War II seem likely. Considerably more power than has yet been exerted will be necessary to push the North Korean aggressors back into their own country, but the consumption of war materiel should not be large. However, the same type of outbreak may be expected from time to time in several other Communist-dominated countries so United Nations forces must be more ready than they were in Korea to oppose force with force. This will mean that a larger proportion of the world's mineral output would be utilized for munitions even though they were not immediately consumed.

The present situation indicates the need for a better organized United Nations police force. Some plan should be ready for execution whereby forces from member countries can be immediately despatched to areas where trouble threatens or military force must be opposed. The United States cannot and should not police the world. The war in Korea had to be assumed for the present by the United States alone, even though it was voted by the United Nations, but it would further the conception of the United Nations idea if no nation, and especially the United States, completely dominated such an effort.

Also, the veto power in the United Nations in such cases as this should be removed. Though Soviet Russia has been blamed for using it to excess, the United States, when the United Nations was organized, was one of those that insisted on this provision in the charter. It was only luck that the Soviet representatives, pouting about the nonrepresentation of Communist China, were absent when the Security Council voted that North Korea, as an aggressor, should be opposed. Had they been present the vote of censure would have been vetoed. No nation should have the power to veto action just because its own interests are concerned. This is just the time when world opinion should govern.

Proponents of world government have long advocated codification of international law. Such law is badly needed in the present instance. It would certainly define what is meant by "aggression." By the Russian definition, the South Koreans or the Americans—it is not entirely clear which—were the aggressors in Korea, cruelly attacking the peaceful inhabitants of North Korea. If this was true it was indeed fortunate that North Korea had immediately available an overwhelming military force that could overrun the aggressor's country as soon as they had fired the first shot across the border.

Will You Help?

All organizations like to grow. It is an indication of health and good management. Growth normally results in greater economy of operation, greater profits to the stockholders, and better and cheaper products for the customers. These factors apply equally to a company owned by stockholders or to a cooperative enterprise like the AIME. With the AIME however, the members are the stockholders and get the profits achieved by growth. The members are also, to a large extent, the customers, getting the benefit of lower unit costs on larger production.

Though the Institute has had remarkable growth—from 7868 members at the beginning of 1934 to 16,344 at present—the membership could easily be 20,000. A more powerful organization, with greater prestige, would result. Meeting attendance would increase, and thus the opportunity for more professional contacts. The financial benefits would be equally great. If 4000 new members were added to the rolls in the next year, and 3000 of them were Associate Members and Members, there would be an increased income of \$60,000 in initiation fees and a like amount in dues. If the other 1000 were Junior Members without initiation fees, another \$12,000 would be added, or \$132,000 in all. The expense of servicing these additional 4,000 members would be nothing like \$132,000. The difference would mean increased services and privileges at a lower cost to members.

Not only would the income from fees be increased by the amount stated, but the circulation of the journals would be expanded by a like amount. This would make them more valuable to advertisers, and higher advertising income should result.

In the last month every member has been asked by mail to suggest the names of good prospects. It is hoped that this request will be productive of a large number of names, of which a good proportion will eventually be found in the Directory. Still more appreciated will be the successful effort of a member to obtain a formal application for membership.

There is no better way in which AIME members can further their own professional society. So send in that card—or a filled-out application—now.

Manganese and Chrome

We are getting no more manganese and chrome ore from Russia. She first served notice late in 1948 that manganese ore shipments would be restricted, and there was much more or less hush-hush palaver in government and steel circles as to what could be done about it. Manganese is an absolute necessity in almost every kind of steelmaking process, nullifying the effect of oxygen and sulphur. From half to three quarters of a pound is used per ton of steel, and with the steel industry operating at over 100 pct of "capacity," a good supply of manganese is vital.

Russia, our No. 1 source, supplied 427,000 tons of manganese ore in 1948, and 81,000 tons in 1949, making token shipments on existing contracts which have now expired. The deficiency has fortunately been made up by increased shipments from the Gold Coast and the Transvaal in Africa, and from India and Brazil. The Nsuta mine, in the Gold Coast, is the largest single source of manganese in the world. These sources made up for the deficiency in Soviet shipments last year. Plenty of manganese exists at various places in the United States but it is too low grade to be commercial. Nevertheless, the deposits have been and are being investigated and concentration methods developed to meet a possible emergency. Also, the 10 pct manganese content of steel-furnace slags is a possible source for investigation.

Chrome ore, like manganese, has to be imported, and to substantially the same amount. Lacking the Russian supply, more will have to be obtained from our other principal suppliers—the Union of South Africa, Cuba, Southern Rhodesia, and the Philippines. Chrome is needed for the refractory and chemical industries as well as for steel.

Russia's cessation of exports was in retaliation for the ban the United States put on shipment of any machinery or capital equipment that might be used for war preparations. This includes practically everything. Their principal export to us now is furs.

AIME Personals

Thomas St. H. Acland is now employed by Booth, MacDonald & Co., Ltd., engineers, Christchurch, N. Z., as an engineer salesman.

Sumner M. Anderson

Sumner M. Anderson, Latin American specialist for the foreign minerals region, U. S. Bureau of Mines, is on a 3-month observation tour of the important mining areas in South and Central America and Mexico. He will collect pertinent information relative to current and potential mineral developments in nine countries.

Gideon A. Apell was transferred from Plateville, Wis., Region V, to Mt. Weather Branch Region VIII, Minerals Div., Bluemont, Va.

Samuel Barker, Jr., was recently honored as a 50-year member of the AIME. Mr. Barker, who is a prominent Butte engineer, was made a member of the Legion of Honor.

Raymond A. Bradbury has been employed by the Armco Steel Co. under a training program.

Arthur A. Brant has closed his offices in Toronto, Canada, and will reside in the United States. He may be reached at P. O. Box 366, Jerome, Ariz.

Henry R. Colen is now employed as geologist with the San Luis Mining Co., Tayoltita, Durango, Mexico. He recently completed work for his E.M. degree at Columbia University.

J. D. Cooner has accepted the position as head of the mining research of the anthracite research laboratory, U. S. Bureau of Mines, Schuylkill Haven, Pa. He was formerly safety engineer at Hudson Coal Co., Scranton, Pa.

Tony J. De Primo, recently graduated from Missouri School of Mines, is now employed as a junior service engineer by Dowell, Inc., Mt. Carmel, Ill.

Henri J. de Wijs is now professor in petroleum and mineralogy at the Technical University, Delft, Holland.

R. W. Diamond, vice-president and general manager of Consolidated Mining & Smelting Co. of Canada, Ltd., recently received the honorary degree of Doctor of Science from University of British Columbia.

Samuel H. Dolbear and **Parke A. Hodges,** Behre, Dolbear & Co., have been doing professional work in the potash area at Carlsbad, N. M.

Lewis W. Douglas, United States Ambassador to England, recently received the honorary degree of Doctor of Laws at Glasgow University.

L. H. Duriez, formerly manager of the Bayard department, U. S. Smelting Refining & Mining Co., Bayard, N. M., has been appointed consulting mining engineer.

Karl R. Fleischman, formerly with Dicksom Primer & Co., Pty., Ltd., has been made superintendent of mines at Herberton, North Queensland, Australia.

Victor G. Ford has recently been appointed general manager of the Sinai Mining Co.'s interests in Egypt, at Abu Zenima, Sinai.

Robert F. Griffith is now employed by the Special Minerals Investigation Branch of the U. S. Bureau of Mines, Boise, Idaho.

Harlowe Hardinge

Harlowe Hardinge, president of Hardinge Co., Inc., York, Pa., recently returned from a 60-day trip to Europe and Africa. He contacted key industrial personnel in England, France, Belgium, Germany, Belgian Congo, Northern Rhodesia, and South Africa.

L. E. Harris, formerly assistant and mill superintendent, Cananea Consolidated Copper Co., Cananea, Sonora, Mexico, is now connected with American Smelting & Refining Co., El Paso. He is a designer in the smelting department engineering office.

Receive Honorary Degrees at Missouri Commencement

E. W. Engelmann, (left) assistant general manager, Kennecott Copper Corp., Salt Lake City, and C. J. Potter (right) president, Rochester & Pittsburgh Coal Co., Indiana, Pa., were given honorary degrees of Doctor of Engineering at the commencement of the School of Mines & Metallurgy, University of Missouri, Rolla, Mo. Dean Curtis L. Wilson is shown with the two recipients.

W. C. Page was elected vice-president and general manager of western operations, U. S. Smelting Refining & Mining Co. He formerly held the position of general manager of western operations.

Bruce R. Pickering has accepted the position as inspector of mines in the Colonial Mines Service, c/o Lands & Mines Dept., Mwanza, Tanganyika Territory, East Africa. He was formerly residing in Dunedin, N.W.I., New Zealand.

J. H. Pollard

J. H. Pollard has opened his own office as a consultant in Houston. He will specialize in construction, engineering, exploration and general advisory capacity. Until recently he held the position as chief engineer for the Duval Sulphur & Potash Co.

Ronald L. Prain was elected chairman of Roan Antelope Copper Mines, Ltd., Rhodesian Selection Trust Ltd., and its subsidiary, Mufulira Copper Mines, Ltd.

Edmund A. Prentis, partner, Spencer, White & Prentis, Inc., New York, was awarded a certificate for his outstanding service in standardization by the American Standards Assn.

Peter F. Ransby has temporarily joined the staff of the Wanderer Consolidated Gold Mines, Ltd., Southern Rhodesia.

Henry J. Schwellenbach has recently joined Warren Foundry & Pipe Corp. in the capacity as mill superintendent of the Mt. Hope mine at Mt. Hope, N. J. He was formerly connected with the National Lead Co., Tahawus, N. Y.

Robert B. Shaffer has taken the position as a mining engineer with the Monsanto Chemical Co., phosphate division, Columbia, Tenn.

William J. Shedwick, Jr., is making a study of the chromite deposits of Guatemala for the Tezuitlan Copper Co. and Fundicion de Acero Electrico.

Francis A. Thomson, president of the Montana School of Mines, was awarded the Distinguished Achievement Medal of the Colorado School of Mines.

Raymond G. Travis has returned from Greece where he was supervising an exploration and development program in diamond core drilling of lignite deposits on the Island of Enboea. He is now working on the investigation and study of the Missouri River Basin in connection with an extensive development program for that area.

K. S. Twitchell recently returned from a 5 months' trip to Iran. **Abbas Zahedi,** an official of Iran's 7-year plan of organization, returned with him and has been studying American mining methods.

Louis Ware was elected vice-chairman of the board, National Fertilizer Assn., at the annual meeting. He is president of International Minerals & Chemical Corp., Chicago.

World Traveler

C. A. Weekley

C. A. Weekley, general mill and smelter superintendent in charge of construction for Marsman Co. of California, recently reported from Genoa that he and Mrs. Weekley are taking a combination business-pleasure trip around the globe. The trip is a leisurely one, on a Danish freighter. Mr. and Mrs. Weekley had already visited Bangkok, Singapore and Penang, and had driven from Suez to Cairo. Leaving Egypt from Port Said, they had next visited several points in Israel. They expected to visit England, Belgium, France, Holland, and sail from Denmark, arriving in New York on July 28. Mr. Weekley's New York address will be c/o Marsman Co., 11 Broadway. He is expected to return to his headquarters in Manila in October. The purpose of his round-the-world trip was to select new equipment which was damaged or destroyed by the Japanese and to study recent metallurgical developments. Mr. Weekley serves as a director of both the San Mauricio and United Paracale Mining companies in the Philippines. His firm is also rehabilitating the Itogon Mining Co. mines and the Coco Grove, Inc., dredging operations there.

Burton J. Westman is returning to the west coast to resume private practice as a consulting mining geologist and diamond drilling engineer. He was formerly connected with the Koebel Diamond Tool Co. as manager of the core bit division.

Raymond E. Zimmerman, chief of mineral preparation division, Pennsylvania State College, has left for Turkey. He will serve as consultant for the Koppers Co. The company is supervising the development and modernization of the Turkish coal basin in the Zonguldak area along the Black Sea.

—Obituaries—

T. H. Aldrich, Jr. (Member 1896), died on May 24 in Florence, Ala. He was born in Selma in 1873, graduated from Purdue University and joined his father in geological research work. He was connected with the early development work of Alabama's mineral resources, opening and operating coal and gold mines in that state. Mr. Aldrich held patents on a rotary dump for coal cars and an attrition process for metallurgical separations. Before and during World War II he was research engineer for Sloss-Sheffield Steel & Iron Co., Birmingham.

John Henry Anderson (Member 1937), retired, died on May 10 in Philadelphia. Mr. Anderson was born in Taunton, Mass. in 1875 and received his education in Vermont and Pennsylvania.

John Rogers Bartlett (Member 1937), assistant general superintendent of mines, Anaconda Copper Mining Co., Butte, Mont., died in May. He was born in 1881 in Chicago, and graduated from the Uni-

versity of Michigan in 1904, receiving the degree of B.S. in C.E. In 1906 he became associated with Anaconda and remained with them in various capacities. In 1924 he was made assistant general superintendent of mines and retained this position until his death.

Allan J. Clark (Member 1897), former chief metallurgist for the Homestake Mining Co., died recently in Spearfish Valley, S. Dak. Mr. Clark was born in 1874, in Jersey City, N. J. and received his E.M. degree from Columbia School of Mines in 1896. He had worked for Tennessee Coal, Iron & Railroad Co. prior to joining the Homestake Mining Co. as an assayer.

William H. Gabeler (Member 1950), who was manager of the Davison Chemical Corp., phosphate rock division, Bartow, Fla., died on April 29. Following his graduation from MIT in 1915, he was assistant superintendent of operations, Barrett Co., Boston. He was then associated with Pennsylvania Water & Power Co.; Davison Chemical Corp.; Summers Fertilizer Co.; and Northern Chemical Industries, all in Baltimore. In 1945 he rejoined Davison Chemical as division manager and engineering administrator in Bartow, Fla.

Charles Hart (Member 1924), died on May 23 in Media, Pa. He graduated from Swarthmore College and took a year of post-graduate work at Lafayette. He went to work as a chemist with Carnegie Steel Co., Pittsburgh, and was then associated with Republic Iron & Steel Co., Youngstown. He was vice-president of Republic when he was transferred to Inland Steel Co. and became president. In 1910 he became owner-president of Delaware Steel Co. of Chester, Pa.

H. M. E. Heinicke (Member 1930), metallurgical engineer, died recently. Mr. Heinicke was born in St. Louis in 1896 and earned his B.S. degree at University of Illinois, graduating in 1919. He worked as a metallurgist for the American Steel Foundries, Indiana Harbor, Ind. for a short time. In 1920 he joined the Western Electric Co., Chicago, as metallurgical engineer, working in die casting, melting, rolling and wire drawing. Several patents were taken out by the company as a result of his work.

W. L. Honnold (Member 1893), internationally known mining engineer and humanitarian, died on May 6 in Los Angeles, after a long illness. Dr. Honnold was born in Oconee, Ill. in 1866. He attended Knox College, University of Michigan, Michigan College of Mining and Technology, and Claremont College. From 1895 to 1902 he was foreman, superintendent, manager, and consulting engineer of mines in Minnesota and California. In 1902 he went to South Africa as consulting engineer for Consolidated Mines Selection Co. (London) and subsidiary companies. He became managing director and chairman, Transvaal Coal Trust, Brakpan Mines, Spring Mines, and the New Era Co. He retired from South Africa in 1915. In 1916 he was transferred to New York as American director of the Commission for Relief in Belgium. He was made director of Anglo-American Corp. of South Africa, Ltd., Hazeltine Corp., Calaveras Cement Co., and Pacific Alkali Co.

Chambers Kellar (Rocky Mt. Member, 1928), of Lead, S. Dak., died in May 1950.

Arthur S. Knoizen

An Appreciation by
Julian D. Conover

Arthur S. Knoizen (Member 1943), executive vice-president and director of the Joy Mfg. Co., died of a heart ailment on April 29 at Franklin, Pa. He was born in Muskegon, Mich. in 1897, spent his boyhood in Weybrun, Saskatchewan, returning to the United States at the age of 16. Following studies in accounting and mechanical engineering and a period of employment with the Aluminum Co. of America, he

became associated with the Joy Mfg. Co., where he came up through the ranks from machinist-welder, foreman, superintendent, salesman to executive positions at the top. He was a pioneer in the development of the coal loading machine, the shuttle car, the continuous miner, and the technique of trackless mechanical mining.

"Art" Knoizen's ability, energy, and wide knowledge of the mining industry were called on in 1942

Arthur S. Knoizen

when he agreed to head the mining division of the War Production Board. In that capacity he was responsible for assuring adequate materials for the manufacture of mining machinery and for maintenance and operation of our coal, metal, and nonmetallic mineral mines. He also headed a government mission sent to Europe to seek means of increasing coal production in England and the allied countries. He worked prodigiously, never sparing himself, and performed an outstanding service in the face of great obstacles.

Arthur Knoizen was above all a dynamic personality; where he was involved, things never got into a rut. His own bold imagination, his courage, and drive in putting his ideas into effect, and the sincerity and conviction which his words carried were major factors in the success of any enterprise with which he was associated. His was likewise a warm personality, which made and kept friends everywhere. His untimely death—truly a war casualty—leaves a void in the hearts of all who knew him.

Clancey M. Lewis (Member 1899), retired executive-secretary of the Manufacturers' Assn. of Washington, died on May 17, in Renton, Wash. Mr. Lewis was born in Minneapolis, graduated from M.I.T. and went to Seattle in 1907. He spent five years in China and wrote several technical papers. He had experience in gold and silver mines.

Robert Carl Matson (M '23), born in Hancock, Mich., in 1894, died on May 14, 1950. He received his E.M. degree from Michigan College of Mines in 1919 and shortly thereafter joined the staff as an instructor in civil and mining engineering. He became assistant professor, associate professor and finally full professor. In 1944 and 1945 he served as head of his department. His practical experience included mining and metallurgical work with several companies including the Quincy Mining Co., Calumet & Hecla Mining Co., and Anaconda Copper Co. He had done extensive research in iron and copper production and authored two textbooks used in the training of mining engineers.

John E. McKay (M '37), former mine superintendent for Rock Products Co., was killed on April 13, 1950 in a mine accident. Mr. McKay was born in Thorburn, Nova Scotia on August 31, 1917. He attended the University of Arizona and received his B.S. in 1940. Following his graduation he was employed as a mining engineer for the Iron King Mining Co., Humboldt, Ariz. He was then employed for a short time as superintendent in charge of installing additional mill equipment for the Zuni Milling Co., Albuquerque, N. Mex. In October 1944 he joined the 79 Lead-Copper Co., Hayden, Ariz., as superintendent in charge of 79 mine, doing exploration work and diamond drilling.

William James Nicholls (M '40) died on May 24, 1950. Mr. Nicholls was born in Ely, Minn., in 1895. He received his M.E. in metallurgy in 1921 from the School of Mines, University of Minnesota. He was employed consecutively as a mining engineer, assayer, smelter, assistant chief chemist and acting chief chemist. In 1929 he joined the International Smelting Refining Co., Tooele, Utah as assistant copper plant superintendent. In 1936 he was made copper plant superintendent for the same company.

H. W. Nichols (M '00), born on December 7, 1866, in Cohasset, Mass., died on June 11, 1950. He graduated in 1893 from M.I.T. receiving his B.Sc. degree. He then became an assistant in geology at that college. Mr. Nichols joined the Field Museum of Natural History, Chicago in 1895. During his years at the museum he was curator, economic geology, assistant curator of geology, associate curator and in 1937 became chief curator until his retirement in 1947. He conducted 16 expeditions; one to South America, two to Canada and 13 to various localities in the United States. On these expeditions he collected mineral specimens and studied mining methods as well as natural phenomena.

Nicolas Reformatsky (M '41), former geologist and petroleum engineer for the Oliver Mining Co., Bolivar, Venezuela, died in January 1950. Mr. Reformatsky was born in Russia in December 1901. In 1925 he graduated from the University of Paris and in 1927, from the Geological Institute of Strasbourg and the Highest National School of Petroleum & Combustible Liquids of Strasbourg, France. He received his Science degree from the University of Paris and a diploma of geological engineer and petroleum engineer from Strasbourg. Following his graduation in 1927 he was employed in the La Houve coal mine, Lorraine, France. He then entered the technical service of the Bataafsche Petroleum Maatschappij, Holland, and at the Dutch East Indies. He also worked with the geological survey for the general government, French West Africa, doing prospecting and geological mapping in colonies. In 1932 he was connected with scientific research work on laterite and rock alteration at the Geological Institute of Strasbourg. In 1935 he became professor of mining and petroleum geology, Mining School of Cuenca, Equador.

Necrology

Date Elected	Name	Date of Death
1900	James B. Bailey	Oct. 1, 1948
1938	Charles B. Carpenter	June 10, 1950
1918	George W. Coffey	July 4, 1950
1939	J. S. Coupal	June 4, 1950
1936	Clyde E. Cowman	March 1950
1931	Octave P. Ebeling	Jan. 16, 1950
1943	Alfred W. Gregg	June 8, 1950
1905	E. T. Henderson	Unknown
1947	Willard S. Johnson	Mar. 26, 1949
1923	Robt. Carl Matson	Apr. 13, 1950
1937	John E. McKay	May 14, 1950
1940	Wm. J. Nicholls	May 24, 1950
1900	H. W. Nichols	June 11, 1950
1941	N. Reformatsky	Jan., 1950
1906	Charles W. Saxman	Unknown
1915	E. C. Wilson	June 12, 1950

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on June 30, 1950, was 16,339; in addition 4256 Student Associates were enrolled.

ADMISSIONS COMMITTEE

E. C. Meagher, Chairman; Albert J. Phillips, Vice-Chairman; George B. Corless, H. P. Croft, Lloyd C. Gibson, Ivan A. Given, F. W. Hanson, T. D. Jones, P. Malozemoff, Richard D. Mollison, and John Sherman.

Institute members are urged to review this list as soon as the issue is received and immediately to write the Secretary's Office, night message collect, if objection is offered to the admission of any applicant. Details of the objection should follow by air mail. The Institute desires to extend its privilege to every person to whom it can be of service but does not desire to admit persons unless they are qualified.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; AM, Associate Member; S, Student Associate.

Alaska
Eska—Tucker, Robert Lester (R—C/S—S-M).

California
Los Angeles—Smith, Jack Wendell (J).
San Francisco—Gould, Malcolm Brown (R—C/S—S-J).

Colorado
Climax—Windolph, Frank J. (C/S—A-M).
Denver—Persse, Franklin H. (C/S—S-J).
Spalding, Edward Charles (C/S—S-J).

Idaho
Wallace—Robinson, Raymond Francis (C/S—A-M).

Minnesota
Minneapolis—Buys, Victor William (M).

Montana
Butte—Damkroger, Donald Albert (C/S—S-J). Hotvedt, Carleston Narvey (C/S—J-M). McCanna, Marcus Edward (M). Parfitt, Paul A
Philipsburg—Nickelson, Howard B. (C/S—J-M).

New Jersey
East Orange—Koons, Charles (M).
Mountain Lakes—Hartmann, Waldemar (M).

New York
New York—Peloubet, Maurice E. (A).

Oklahoma
McAlester—Puterbaugh, Jay Garfield (R—C/S—A-M).

Pennsylvania
Hazelton—Roderick, David John (A).
Narbeth—Allen, Homer Edgar (M).
Oakmont—Parker, Glen Lawhon (M).
Paoli—Berry, Bernard C. (M).
Pittsburgh—Ballard, Clarence Wesley (M).
Plains—Cardoni, Frank (A).
Punxsutawney—Hampton, William Henry (C/S—A-M).
Taylor—James, Russell Emerson (A).
Uniontown—Beerbower, Ralph C., Jr. (R—C/S—S-J).
Worthington—Druschel, William Pascoc (M).

South Dakota
Lead—Bromfield, Calvin Stanton (R—C/S—S-J).

Tennessee
Isabella—Dorenfeld, Morton Harvey (C/S—S-J).

Texas
Dumas—Calhoun, Ralph Emerson (R—M).
El Paso—Cope, Louis W. (C/S—S-J).
Park City—Bracken, Everett Owen (C/S—S-J).

Ontario
Kirkland Lake—Cook, Forrest Maillard (R—C/S—S-M).

Bolivia
Oruro—Muysken, Pieter Joan (J).

Afghanistan
Kabul—Walter, Albert Joshua Petrie (M).

Austria
Carinthia—Awerzger, Arnold (M).

India
Bombay—Patel, Chimanlal Vallabhbhai (M).

France
Paris—Camplo, Jean (M).

Japan
Tokyo—Kurushima, Hidesaburo (R—M).

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SPACE RESERVATION	— 1st	PRECEDING	MONTH
PLATES IN NEW YORK	— 7th	"	"
MAGAZINE ISSUED	— 23rd	"	"

* Previous Issues